AD-A081 055 GRUMMAN AEROSPACE CORP BETHPAGE NY F/G 1/3
INVESTIGATION OF MINIMUM SIZED LOW-PROFILE COCKPITS (MSLPC) AND--ETC(U)
SEP 79 W C TAUBY F33615-78-C-3427
UNCLASSIFIED AFFDL-TR-79-3104 NL

1 OF 3
AD
A081055

AD A 081 055

LEVEL II

AFFDL-TR-79-3104

DDC FILE COPY

INVESTIGATION OF MINIMUM SIZED LOW-PROFILE COCKPITS (MSLPC) AND CREW ESCAPE SYSTEM INTEGRATION

W.C. Tauby, et al.
Grumman Aerospace Corporation
Bethpage, New York 11714

SEPTEMBER 1979

Final Report for Period 15 September 1978 — 17 July 1979

Approved for public release; distribution unlimited.

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AFB, OHIO 45433

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

This technical report has been reviewed and is approved for publication.

CHARLES V. MAYRAND
Program Engineer

EDWIN R. SCHULTZ, Chief
Crew Escape & Subsystems Branch
Vehicle Equipment Division

FOR THE COMMANDER:

AMBROSE B. NUTT, Director
Vehicle Equipment Division

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization please notify AFFDL/FER, W-P AFB, OH 45433 to help us maintain a current mailing list."

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

AIR FORCE/56780/13 February 1980 — 100

DISCLAIMER NOTICE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFFDL-TR-79-3104
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): INVESTIGATION OF MINIMUM SIZED LOW-PROFILE COCKPITS (MSLPC) AND CREW ESCAPE SYSTEM INTEGRATION, [redacted]
5. TYPE OF REPORT & PERIOD COVERED: FINAL REPORT, 15 Sep [redacted] 78-17 Jul [redacted] 79
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): William C. TAUBY ~~et al.~~
8. CONTRACT OR GRANT NUMBER(s): F33615-78-C-3427
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Grumman Aerospace Corporation, Bethpage, New York 11714
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Program Element 62201F, Project 2402 Task 240203, Work Unit 24020323
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Flight Dynamics Laboratory (FER), Air Force Systems Command, Wright Patterson Air Force Base, Ohio 45433
12. REPORT DATE: 17 Sep [redacted] 79
13. NUMBER OF PAGES: 236
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 237
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: -
16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Crew Escape Integration; High Acceleration Cockpit; Low Profile Advanced Fighter Aircraft; Low Profile Cockpit; Supine Escape System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of the MSLPC study was the assessment of the potential benefits derived from the application to advanced fighter aircraft configurations and the integration of an effective crew escape capability. Alternate approaches and escape concepts were identified and subjected to analysis and tradeoff to permit the recommendation of preferred concepts. The computer simulation of escape system aerodynamic performance facilitated the evaluation leading to the selection of the supine concept as that preferred for further development as a preliminary design.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

388847

FOREWORD

This report was prepared by Grumman Aerospace Corporation, Bethpage, New York under Air Force Contract No. F33615-78-C-3427. The work was accomplished under Project 2402, "Vehicle Equipment Technology", work unit 24020323 "Low Profile Cockpit and Crew Escape System Integration" during the period from 15 September 1978 through 17 July 1979. It was administered under the direction of the Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, with Mr. Charles V. Mayrand acting as Program Engineer.

Mr. William C. Tauby served as the Program Manager and Principal Investigator for the technical work. Considerable assistance in the investigation was provided by Mr. James P. Murray, Jr., Escape System Design Engineer and Mr. Leonard H. Wright, Aerodynamic Performance Project Engineer. Mr. James Martin of the Martin-Baker Aircraft Co., Ltd. served as consultant on escape system design concepts.

CONTENTS

CONTENTS (Contd)

CONTENTS (Contd)

ILLUSTRATIONS

ILLUSTRATIONS (Contd)

ILLUSTRATIONS (Contd)

ILLUSTRATIONS (Contd)

TABLES

TABLES (Contd)

GLOSSARY OF TERMINOLOGY

ABBREVIATIONS, SYMBOLS, & ACRONYMS

AMP	Aircraft maneuvering parameter
ATS	Air-to-surface technology evaluation & integration study
A/C	Aircraft
α	(Alpha) angle of attack
$C_{D_{MIN}}$	Three-dimensional drag coefficient
CDA	Axial drag coefficient
CDAF	Configuration development of advanced fighters
CG	Center of gravity
CISE	Computerized initial sizing estimate
Δ	Change in, difference between, delta, incremental
ΔC_{D_o}	Delta three-dimensional zero lift drag coefficient
ΔC_{η_β}	Delta directional stability derivative ($dC_\eta/d\beta$)
FRL	Fuselage reference line
G	Acceleration unit (physiological)
g	Acceleration unit (aerodynamic)
HAC	High acceleration cockpit
HAPP	High speed aerodynamic prediction program
HRL	Horizontal reference line
KLB	Thousand pounds
LB	Pounds
M	Mach number
M^2	Meters squared

$M	Million dollars
MLCCM	Modular life cycle cost model
MSLPC	Minimum size low-profile cockpit
NSRP	Neutral seat reference point
O&S	Operation and support
PSF	Pounds per square foot
"q"	Dynamic pressure
RAM	Radar absorbent material
RCS	Radar cross section
RAVES	Rapid aerospace vehicle evaluation system
S	Wing area
SEC	Seconds
SRP	Seat reference point
STA	Station
TOGW	Take off gross weight
TVC	Thrust vector control
T/W	Thrust over weight ratio
UE	Unit equipment
W/S	Wing loading (lb/ft^2)

IDENTIFIERS (INPUT PARAMETERS FOR CREW SYSTEM LCC)

		Unit
NOACMFG	Number of aircraft manufactured	Integer
NOCREW	Number of crew per aircraft	Integer
UTLRATE	Utilization rate	Hours/year
MAXMACH	Maximum Mach number at optimum altitude	Ratio
FHPAC	Flight hours per aircraft	Hours/month
PROTO	Prototype aircraft	Integer
TYPSEAT	Type of seat	Factor

GLOSSARY OF TERMINOLOGY (Contd)

		Unit
NOENG	Number of engines	Integer
NOSEATS	Number of seats per aircraft	Integer
LRNCSS	Learning curve slope - subsystems	Decimal
FSLGDEN	Fuselage density	Lb/cubic feet
TFF	Time of first flight months since 1 January 1950	Months
NOACPSQ	Number of aircraft per squadron	Integer
NOBSE(i)	Number of bases with (i) squadrons	Integer
TOTHRST	Total of thrust per aircraft including afterburner, if any	Lb
FSLGVOL	Fuselage volume	Cubic feet
NOAC	Number of operational aircraft	Integer

I. INTRODUCTION

Recent study efforts to define viable advanced technology air vehicle requirements and configurations now provide the broad background to assess the potential of Minimum Size Low-Profile Cockpit (MSLPC) concept and the integration of crew escape system concepts. This study determined the attendant performance and effectiveness benefits and integration considerations of implementing the MSLPC in the various candidate air vehicle classes being examined for application to next generation tactical fighter aircraft. It also suggests profitable variations to the baseline MSLPC, identifies the crew escape provisions, and defines an overall plan for follow-on exploratory development.

Each weapon system component must be conceived, integrated, and implemented to successfully achieve three goals to be of real value:

- Significantly reduce the enemy's attack envelope (i.e., have fewer losses)
- Significantly increase its own attack envelope (i.e., have more kills)
- Have an affordable cost.

While the need exists for complex analysis and design processes to assure reduced losses, increased kills and reduced cost cannot be understated; a more simplistic synthesis is valuable for obtaining problem insight and solution guidance. Such an approach is illustrated in Figure 1-1, where the motivation is for reduced air vehicle gross weight as a measure of both reduced cost and increased survivability. Attendant to reducing weight is, of course, the ability of the air vehicle to exploit technology to perform its mission with smaller but more efficient components for decreased drag and reduced fuel consumption. The wing and engines are obviously candidates in this smaller but more efficient category. The crew station, or cockpit, also falls into this category.

The crew station impacts air vehicle size, performance, effectiveness, and cost, through its own weight, drag, and observables signature; and, indirectly, through its adverse impact on other components (for instance, an increased vertical tail size to offset the destabilizing effect of the canopy).

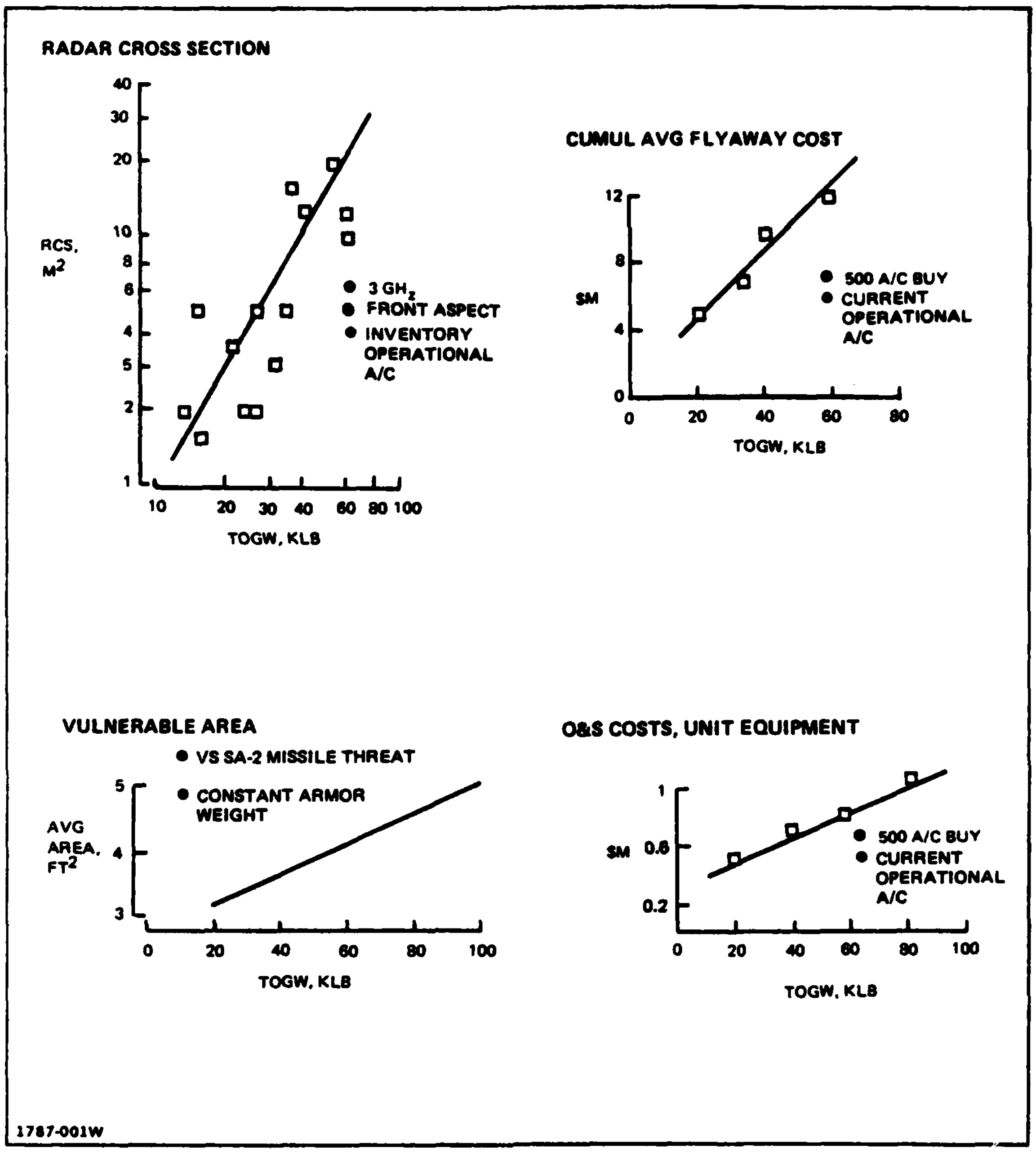


Figure 1-1. Air Vehicle Technology and Effectiveness

The inherent constraints the cockpit may put on the pilot's ability to carry out complex functions at the limits of the aircraft's capability are also significant. The High Acceleration Cockpit (HAC) seat improves pilot performance during high-g maneuvers, but contributes little to reducing profile penalties (drag and stability) or observable signatures, and imposes some additional

weight for escape sequence function due to seat articulation. The MSLPC concept provides profile penalty relief at no apparent weight penalty and has the potential for lower observables, but it imposes a challenging design problem and requires a new escape system concept to provide a safe escape capability for the semi-supine pilot.

This study is devoted to quantifying the benefits of the MSLPC, integrating a feasible escape system concept, developing a preliminary design for a preferred concept, and identifying the future effort. The program draws from both the extensive aeromedical and aircraft cockpit technology data base of the HAC program and advanced fighter requirements, and configuration study efforts such as ATS, Supercruiseval, and the AFFDL/Grumman Configuration Development of Advanced Fighters (CDAF) Study.

The results of assessments of the required characteristics for future fighter aircraft have stressed the need for increased combat effectiveness and survivability, and a reduction of complexity and costs. These basic needs, coupled with advanced aircraft configuration studies and technology advances in HAC, have focused renewed interest in the potential payoffs afforded by the MSLPC concept.

The primary feature of the MSLPC concept is that the cockpit is configured around a pilot situated in a semi-supine position with seat back fixed at a high recline angle. This results in a significant decrease in cockpit height, which may yield reductions in drag and observables and contribute to reduced aircraft size, weight, and costs. Since the semi-supine pilot position is based on the 65° reclined high G position developed under the HAC program, the MSLPC concept also provides the corresponding increased pilot effectiveness in the sustained high acceleration environment. In addition, the MSLPC concept has potential payoffs for advanced fighter aircraft where reduced supersonic wave drag and minimum size and cost are the primary goals.

The basic idea of reducing cockpit size and profile to enhance aircraft performance has a long history of investigation and application to military aircraft. The current high level of interest stems from the conclusion that the reduced size, weight, and complexity afforded by the MSLPC concept can contribute to increased fighter aircraft combat effectiveness and survivability, as well as reduced costs. This conclusion was based on results of advanced fighter aircraft configuration studies and the contemporary results of the HAC program which

also provides much of the criteria in the areas of pilot restraint, head support, side controller, instrument panel, and control locations applicable to MSLPC. The investigation of pilot work load, advanced controls and displays systems was beyond the scope of this effort. Emphasis was placed on the MSLPC configuration, the aircraft interface, and the crew escape system integration.

The investigation of MSLPC and Crew Escape System Integration established a baseline cockpit configuration, identified compatible escape system concepts, and determined benefits derived from the application to high performance fighter aircraft. The baseline cockpit configuration is a fixed version of the 65° recline position developed in the HAC program. Escape system concepts which integrate effectively with MSLPC were identified and evaluated for three performance envelopes: zero to 450 KEAS, zero to 600 KEAS, and zero to 687 KEAS. A preferred concept was identified for each performance envelope and a preliminary design was developed for the zero to 687 supine concept. The MSLPC was applied to a M 1.6 light weight fighter configuration and a M 2.0 penetration fighter configuration developed in the CDAF program.

The selection of the supine concept as the preferred escape system was the result of the concepts development and evaluation (Figure 1-2) presented in this report. In Subsection 4.4 the performance for several concepts was evaluated: the curved track; "B" seat variant; canopy/shield; and supine concept. The primary emphasis during the initial phase of study was directed toward the high speed environment where escape problems were considered to be more critical. The simulations were restricted to the pitch plane and the aircraft was in level flight for most ejections. It was during this phase that the thrust vector control concept was introduced and the importance of an active attitude control system was clearly demonstrated for high speed ejections. Rocket thrust characteristics were sized and rocket locations and orientations were explored. The sizing of the drogue chute was initiated during this phase, and a relationship between drogue canopy size and spinal G at high speed was investigated. In Subsection 4.5 the definition and evaluation of the MSLPC compatible escape system concepts, which have a capability for intermediate performance envelopes defined by the speed ranges of 0 to 450 KEAS and 0 to 600 KEAS, were determined. The emphasis during this phase was placed on the adverse attitude and dive conditions where ejections were calculated in three dimensional space. The advantages of using a vertical steering control system were clearly demonstrated

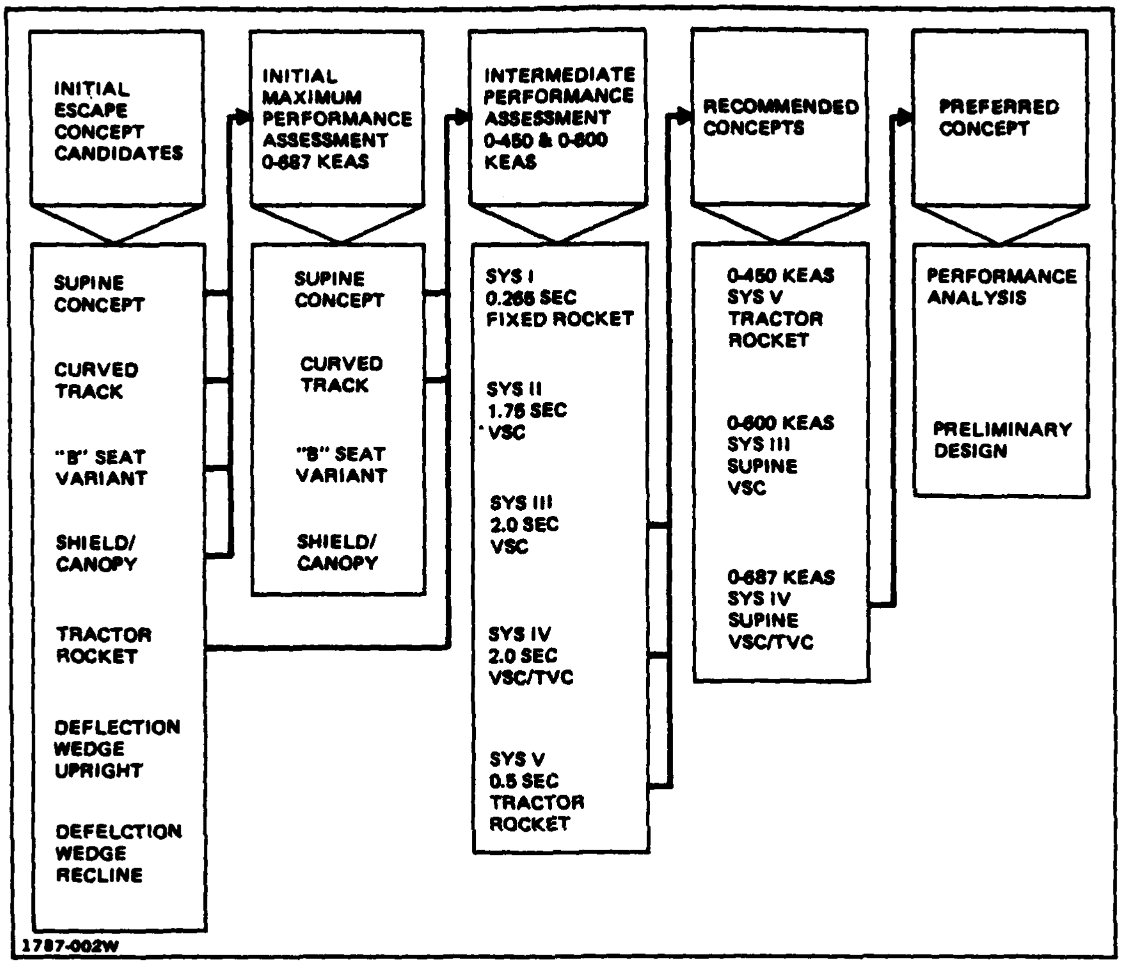


Figure 1-2. Escape Concepts Development and Evaluation Program

here. Further sizing of the rocket thrust characteristics and their effect on the vertical steering control system were investigated during this phase.

Included in Subsection 4.6 are descriptions of all major subsystems resulting from the preliminary design of the supine seat. The description includes an evolution of each subsystem, how they were sized, and what tradeoffs were involved in their selection. The systems described are:

- Seat booster (catapult)
- Seat rocket
- Rocket control
- Drogue parachute
- Main parachute.

This phase of the study is similar to the investigation presented in Subsection 4.5 in that the 11 flight conditions exercised previously were utilized again for this preliminary design effort. However, in addition to spatial trajectory plots, time histories of the seats' angular motion are presented, as well as the G loading on the crewman throughout the ejection.

II. MINIMUM SIZE LOW-PROFILE COCKPIT (MSLPC) DEFINITION

The study was structured to evaluate the MSLPC concept in various projected air-to-air and air-to-ground fighter aircraft configurations. To this end, a baseline MSLPC was defined and used for both the development of escape system concepts and the evaluation in fighter applications.

2.1 BASELINE MSLPC CONFIGURATION

The MSLPC baseline configuration shown in Figure 2-1 served as the representative low profile cockpit in the evaluation of fighter applications and the development of complementing escape system concepts. For the purpose of this investigation, the MSLPC baseline configuration includes the following elements:

- 65° seat back High Acceleration Cockpit (HAC) geometry
- Right-hand (RH) side flight controller
- Left-hand (LH) side throttle
- High authority (i.e., limited movement) rudder pedals
- MIL-STD-850B fighter visibility
- 5th through 95th percentile pilot population
- Standard personal equipment, including G suit but excluding pressure suit
- Forward instrument panel/Head Up Display (HUD)/side consoles.

Minimum MIL-STD-850B fighter visibility requirements (11° down forward and 40° down side) were applied. The anthropometry of flying personnel, supplemented by data and design criteria found in Ref. 1, was used to determine the clearance envelope for the pilot and was confirmed through use of the AMRL two-dimensional, one-quarter scale 5th and 95th percentile drawing board manikins. The control and display arrangement used in the baseline MSLPC was based on the criteria developed under the HAC program (Ref. 2).

2.2 CREW STATION GEOMETRY CRITERIA

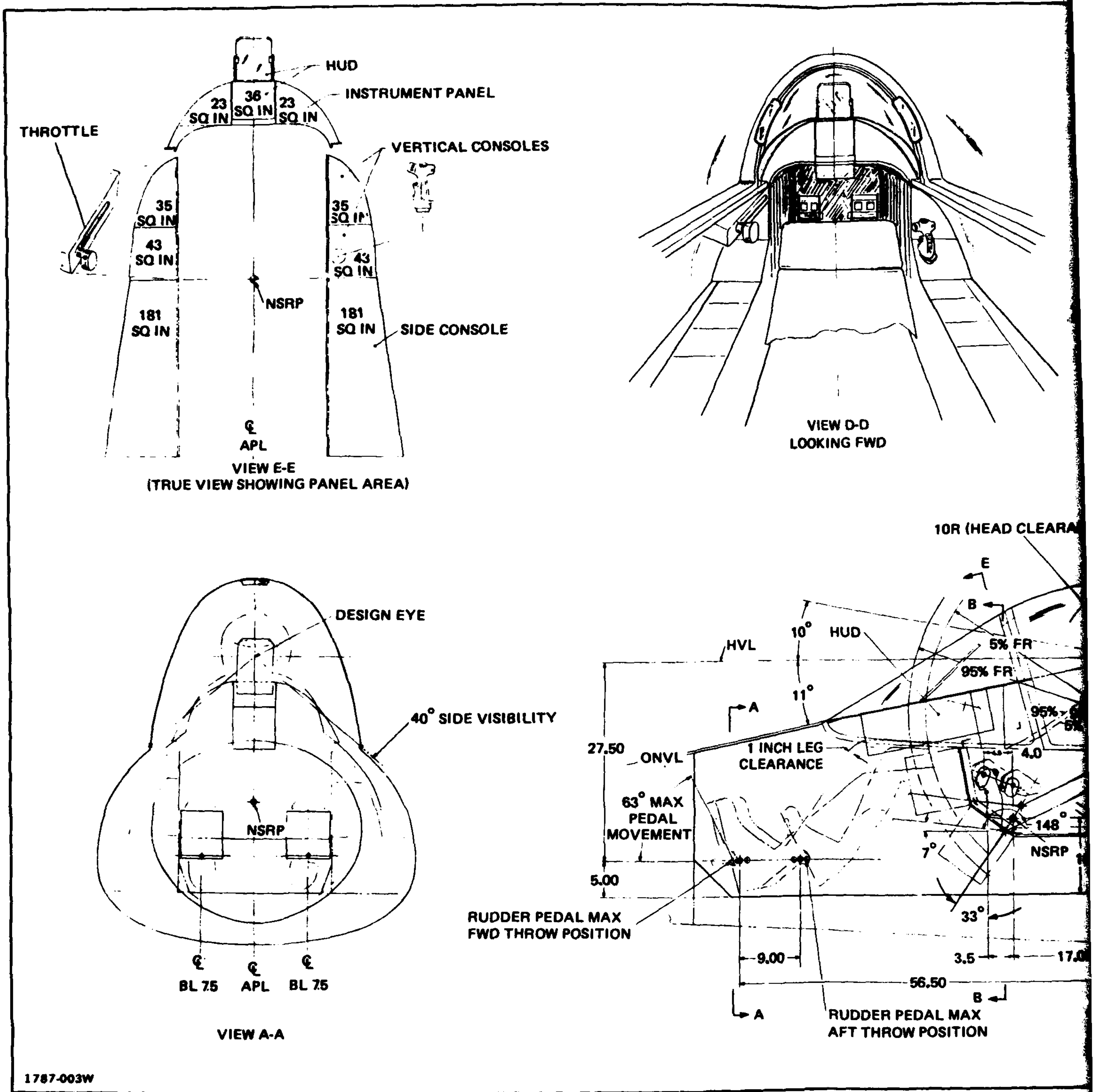
In as much as the MSLPC baseline geometry is based on HAC criteria, a description of the HAC geometry is necessary to provide a reference for further discussion. The HAC application study (Ref. 1) was based on a standard cockpit geometry and an existing ejection seat escape system modified to incorporate articulation of the pilot to a recline position (Figure 2-2). The HAC elements of the resultant crew station geometry were consequently compromised by the constraints of the ejection seat escape system. The ejection seat geometry, as specified by MIL-S-9479B, establishes a relationship between the pilot backrest angle and the headrest. The relationship between the backrest angle and the design eye position is described on SNI(1) and SNI(3) of AFSC DH 2-2. The eye to headrest relationship during normal flight control conditions (upright 15° seat posture) results in space between helmet and headrest. The headrest is functional only during an ejection to support the head against wind blast. In the MSLPC, however, the pilot is in a fixed recline position and the head/helmet is in continuous contact with the headrest.

2.3 HUMAN FACTORS CONSIDERATION IN MSLPC GEOMETRY

The high acceleration cockpit was conceived as a means of increasing the level of a pilot's G tolerance. The John W. Burns study of a Tilt-Back seat (Ref. 4) concludes that the level of G tolerance is a function of the hydrostatic column distance from the eye to the aorta which varies according to the included angle between a vertical reference line and a line connecting the eye and aorta.

The application of HAC requirements to a standard cockpit geometry had an immediate effect on the location of the pilot's head. The recline pilot position, which makes positive head support mandatory, produced a head aft displacement of approximately 6 inches. As a result, the HAC crew station has two eye positions (Figure 2-3) which are accountable with respect to the external visibility related to flight conditions and internal visual access related to the location of control and information displays.

Since the MSLPC concept is based on a fixed geometry, adjustable only for pilot size, it was considered expedient to reexamine the headrest angle. Earlier in-house examination of the HAC concept revealed a problem of pilot discomfort from the reclined tight head/chin on chest condition. In the interest of alleviating this problem, the headrest angle was increased from 17° to 40°. Using the AMRL manikins for measurements, the HAC and MSLPC retinal-aorta relation-


HUD
INSTRUMENT PANEL
36 SQ IN
23 SQ IN
23 SQ IN
THROTTLE
VERTICAL CONSOLES
35 SQ IN
35 SQ IN
43 SQ IN
43 SQ IN
NSRP
181 SQ IN
181 SQ IN
SIDE CONSOLE
℄ APL
VIEW E-E
(TRUE VIEW SHOWING PANEL AREA)
VIEW D-D
LOOKING FWD
DESIGN EYE
40° SIDE VISIBILITY
NSRP
℄ BL 7.5
℄ APL
℄ BL 7.5
VIEW A-A
10R (HEAD CLEARA
E
B
10°
HUD
5% FR
95% FR
HVL
11°
A
95%
27.50
ONVL
1 INCH LEG
CLEARANCE
4.0
63° MAX
PEDAL
MOVEMENT
148°
NSRP
7°
5.00
RUDDER PEDAL MAX
FWD THROW POSITION
33°
9.00
3.5
17.0
56.50
B
A
RUDDER PEDAL MAX
AFT THROW POSITION
1787-003W

RETINAL/AORTA RELATIONSHIP		5 PERCENTILE	95 PERCENTILE
ANGLE,°	HAC	10	12
	MSLPC	26	28
HEIGHT, IN.	HAC	8.8	10.4
	MSLPC	8.8	9.6

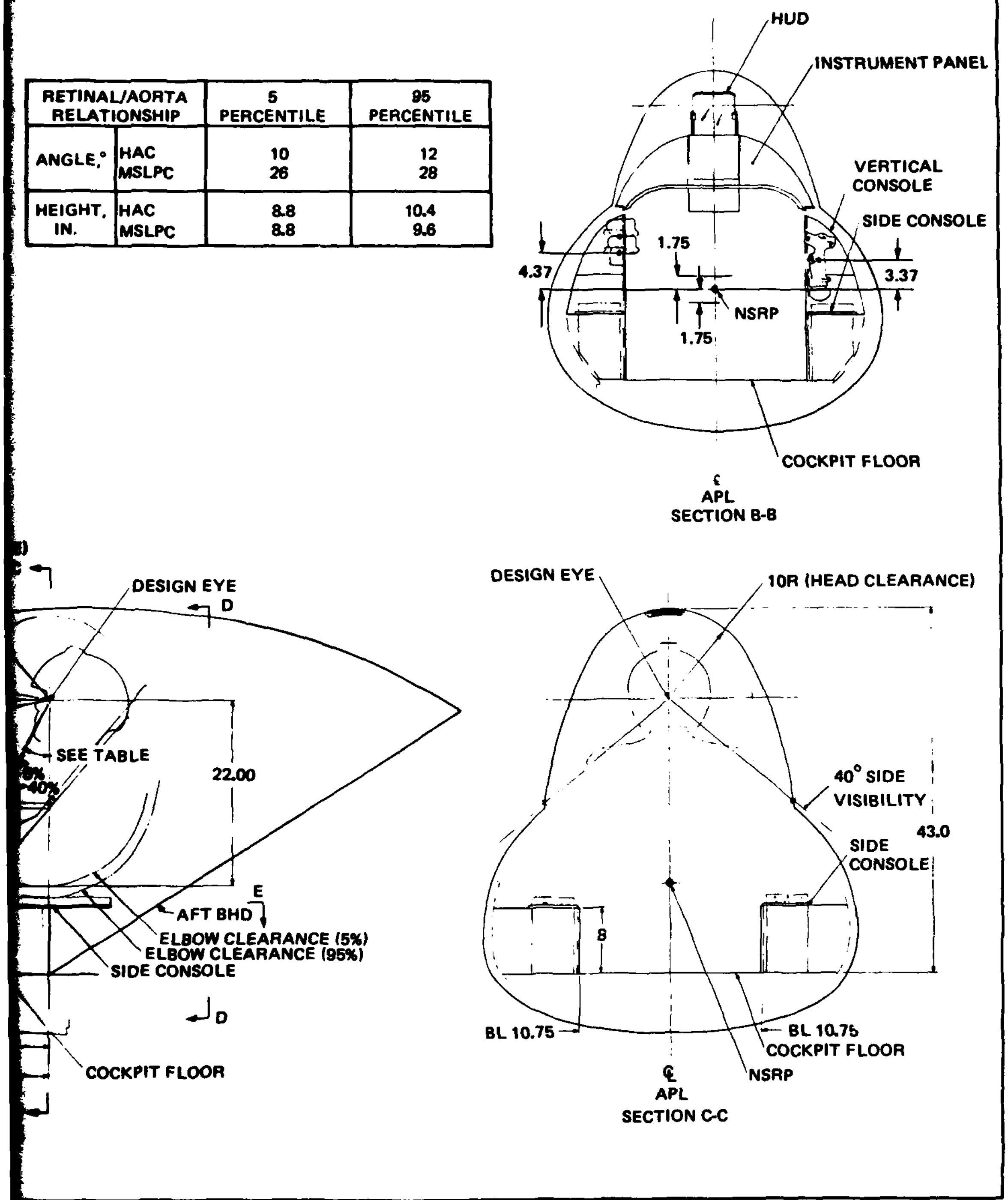


Figure 2-1. MSLPC Baseline Configuration

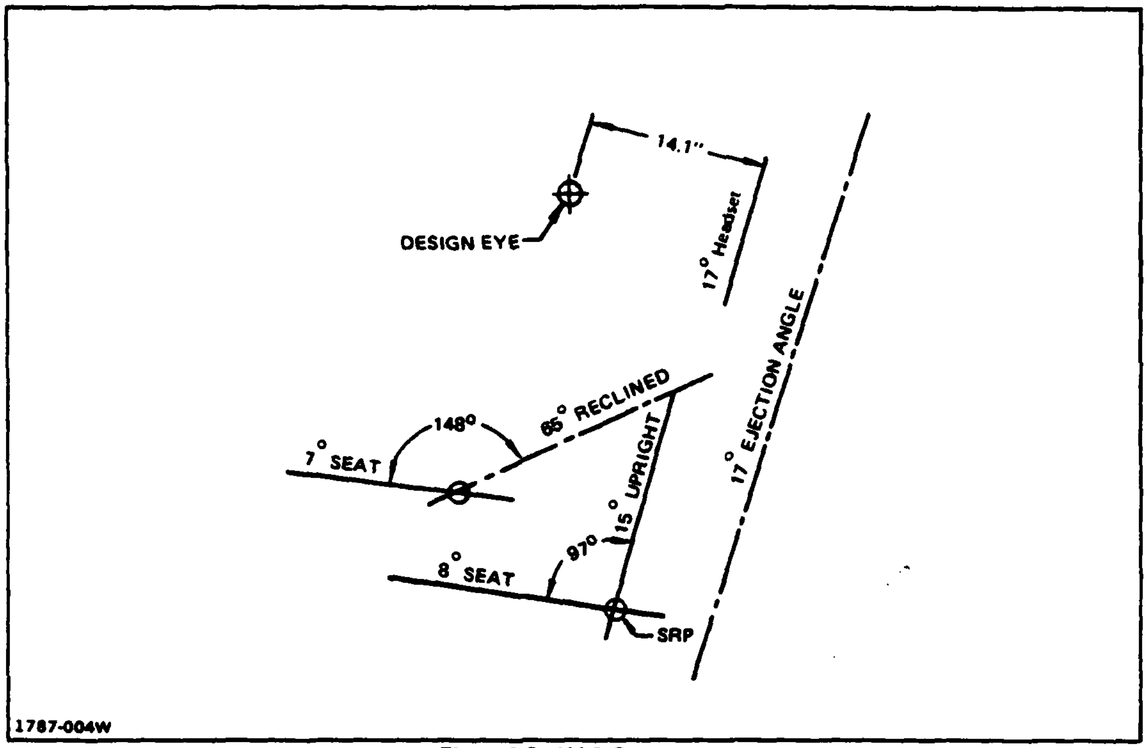


Figure 2-2. HAC Geometry

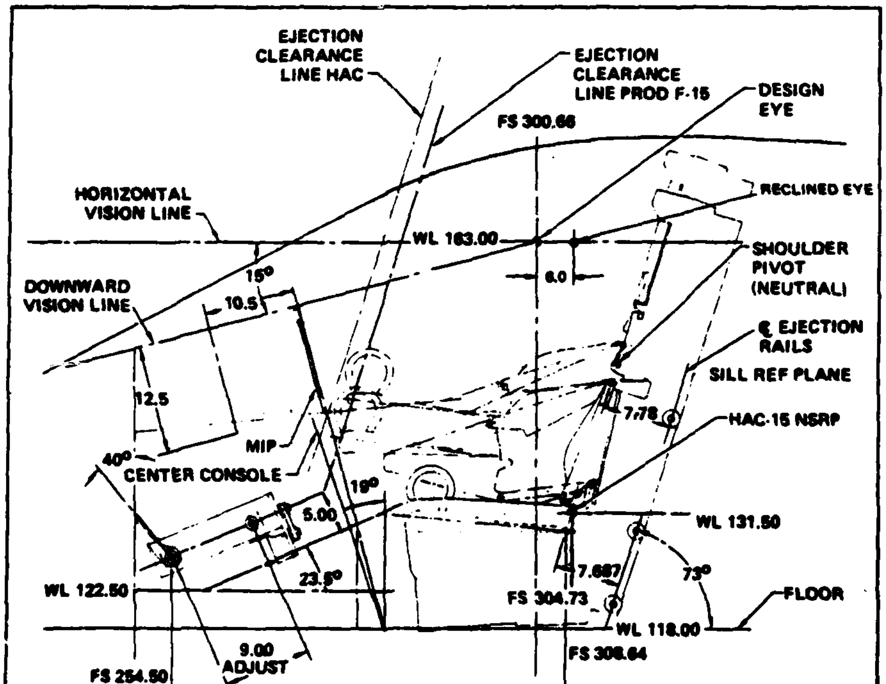
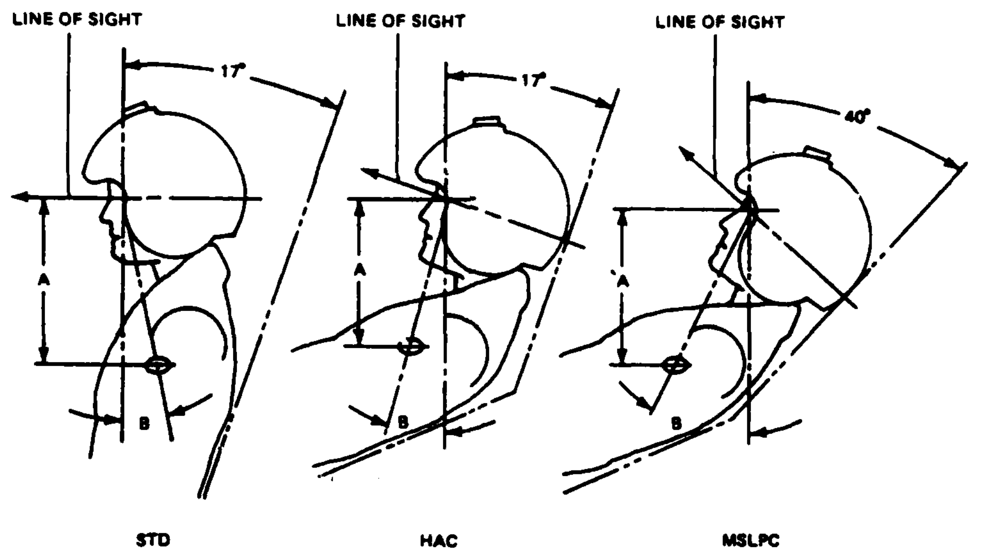


Figure 2-3. HAC Crew Station Geometry

ships are shown in Figure 2-4. An additional pilot performance benefit is derived from the larger headrest angle in terms of increased G tolerance resulting from the shorter hydrostatic column.

The provision of support, comfort, and restraint for the pilot in the MSLPC is a critical area. The simple seat/pedal anthropometric adjustments reflected in the baseline geometry are an adaptation of a standard ejection seated cockpit geometry. It is adequate for positioning the pilot's head at the design eye point and adjusting the rudder pedals to suit. Body support consists of interconnected seat pan, backrest, and headrest surfaces fixed in size and angular relationship. The inherent comfort in the recline position is supplemented by cushions designed for pressure point relief. The primary restraint system is similar to the HAC system, but modified for fixed support surfaces.

The three-plane (surface) support concept provides little flexibility for accommodating anthropometric variables involving head, neck, shoulder, back,



MEASURE / CREW	ANGLE B, °			HEIGHT A, IN.		
	STD	HAC	MSLPC	STD	HAC	MSLPC
5 PERCENTILE PILOT	16	10	26	11.5	8.8	8.8
95 PERCENTILE PILOT	15	12	28	13.5	10.4	9.6

1787-006W

Figure 2-4. Relationship of Retinal-Aorta and Headrest Angle

and buttock relationships. Future development should include consideration for a multi-surface independent adjustment support concept (Figure 2-5), which features up/down/pitch adjustments of individual support elements for the head, upper back, lower back, buttocks, and feet, and would provide more effective body support. The benefits of independent element control can be summarized as:

- Pressure point relief
- Individually tailored support, optimized fit
- Optimized visibility
- Optimized G tolerance.

The capability of the multi-surface, independent adjustment concept could be extended to include automatic increase of the headrest angle to provide flex spine relief, and automatic increase of the seat-pan pitch angle to provide a more effective structural platform to react the compression loads on the spinal column during the aerodynamic deceleration phase of the emergency escape or during crash conditions. Obviously the benefits of such a system will involve tradeoffs with the added complexity and costs involved.

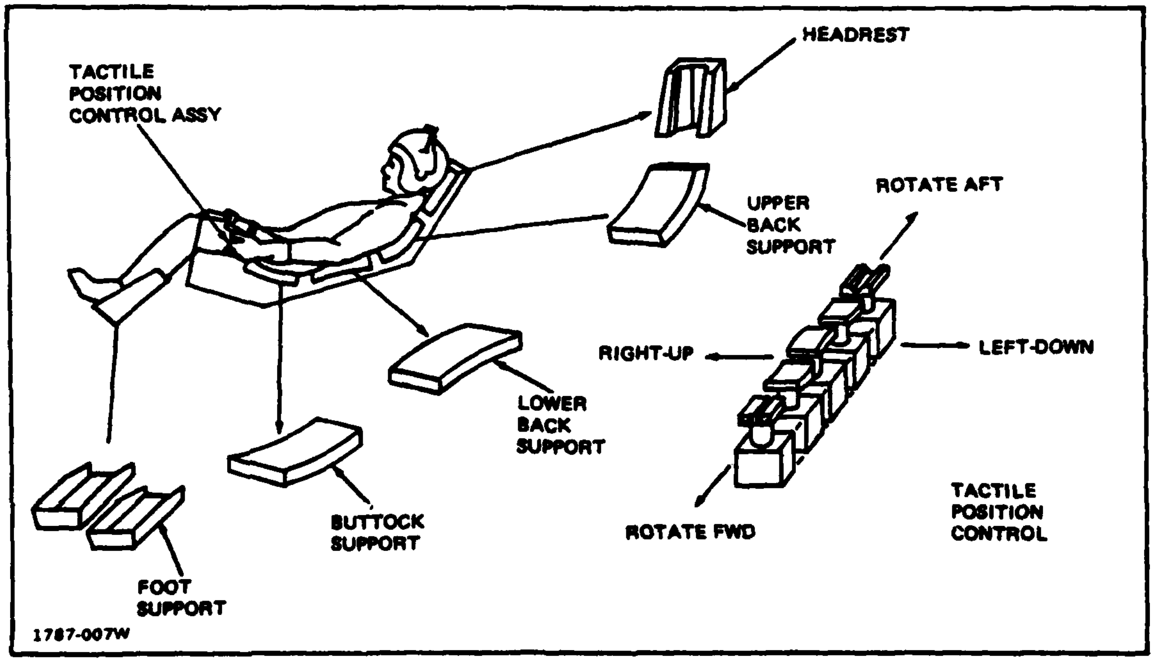


Figure 2-5. Multi-Surface Support Concept

2.4 MSLPC VISIBILITY CONSIDERATIONS

The MSLPC concept presents a completely new visibility environment to which the pilot must adapt. The fixed relationship between the head and torso in the recline position during all phases of the mission flight profile (unlike the HAC) imposes a sustained constraint on the pilot's head mobility. In view of the disparate requirements of external and internal visibility for a high performance fighter, MSLPC visibility considerations were examined during the study.

2.4.1 Visibility Requirements

Although the external visibility requirement for a particular aircraft type can be found in terms of a minimum transparency provision (MIL-STD-850), it is usually not available in terms of a specific functional requirement for mission purposes. Flight control of the aircraft weapon system is dependent to some degree upon external visibility for takeoff, traffic avoidance, target acquisition, weapon delivery, defensive maneuvers, formation flying, and landing approach, all of which are experienced in a dynamic visual environment. Viewing distances are measured in feet and discrimination is affected by time (day/night) and weather (clear/cloudy).

The internal visibility requirement, on the other hand, is related to a static or unchanging visual environment. The information displayed and controls positioned are continuously changing, but the location of a particular function is fixed within the cockpit. Viewing distances are measured in inches and discrimination is optimized through design control of the size, location, lighting, and air condition.

2.4.2 Physiological Limitations

The horizontal and vertical binocular visual field, with head and eye motionless, is shown in Figure 2-6. The visual field can be extended by eye, head, or body movement. Eye rotation extends the field to the limits of facial contour interference. A shift from one visual fixation point to another is accomplished most quickly by eye rotation alone when several shifts in succession and small angular changes ($<15°$) are involved. A fixation point held for more than a few seconds or a change in line of sight of more than 15° is generally accompanied by head rotation. Orientation with surroundings (internal and external) is established when the head is held stationary. The level of disorientation is related to the degree and rapidity of head movement.

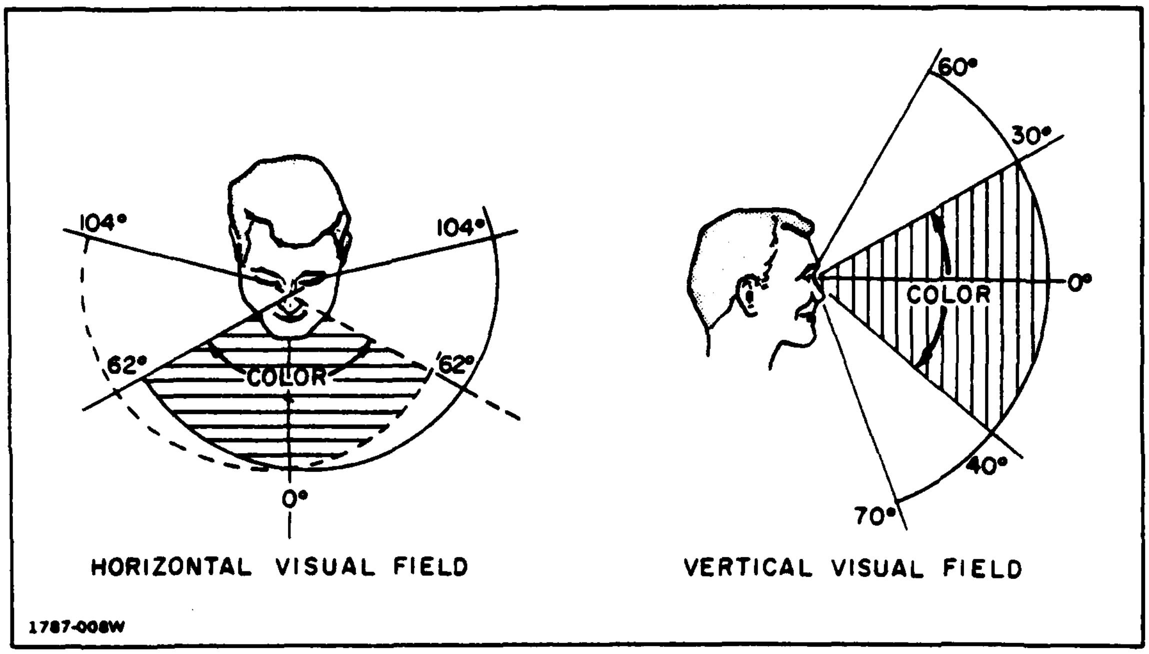


Figure 2-6. Binocular Visual Field

The optimal internal viewing distance is a function of the size of the display. In order to avoid severe strain on eye muscles, the viewing distance should always be more than 13 inches and, preferably, at least 20 inches.

2.4.3 Equipment Design Limitations

The aircraft transparencies, escape system back and head support, and the personal equipment worn by the pilot, present material limitations to the visual field. The MSLPC baseline geometry establishes the physical relationship between the pilot and the aircraft. The resultant relationship between the vertical visual field (Figure 2-6) and the aircraft transparencies is shown in Figure 2-7. Using the monocular "design eye" as a point of reference, the limitations imposed by the windshield/canopy structure are plotted (Figure 2-8).

Visibility is measured as an area limited by the helmet and oxygen mask projected along a line of sight normal to a support reference plane established by the pilots head position as related to back rest and head rest angles (Figure 2-4). The 17° head rest angle in the standard (STD) geometry is not in contact with the helmet during normal aircraft operation. The head and helmet are erect and the support plane of reference is assumed to be vertical. The line of sight for the visibility area of the STD geometry is therefore zero degrees. The 65° back rest in the MSLPC geometry results in the pilot's head/

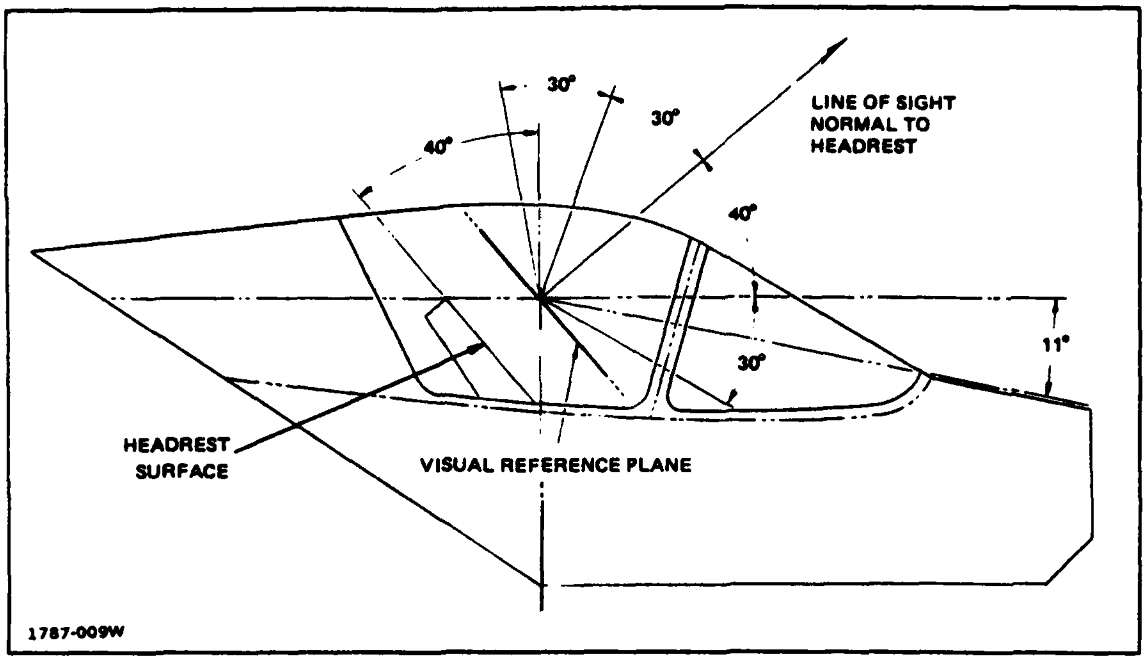


Figure 2-7. MSLPC Vertical Visual Field

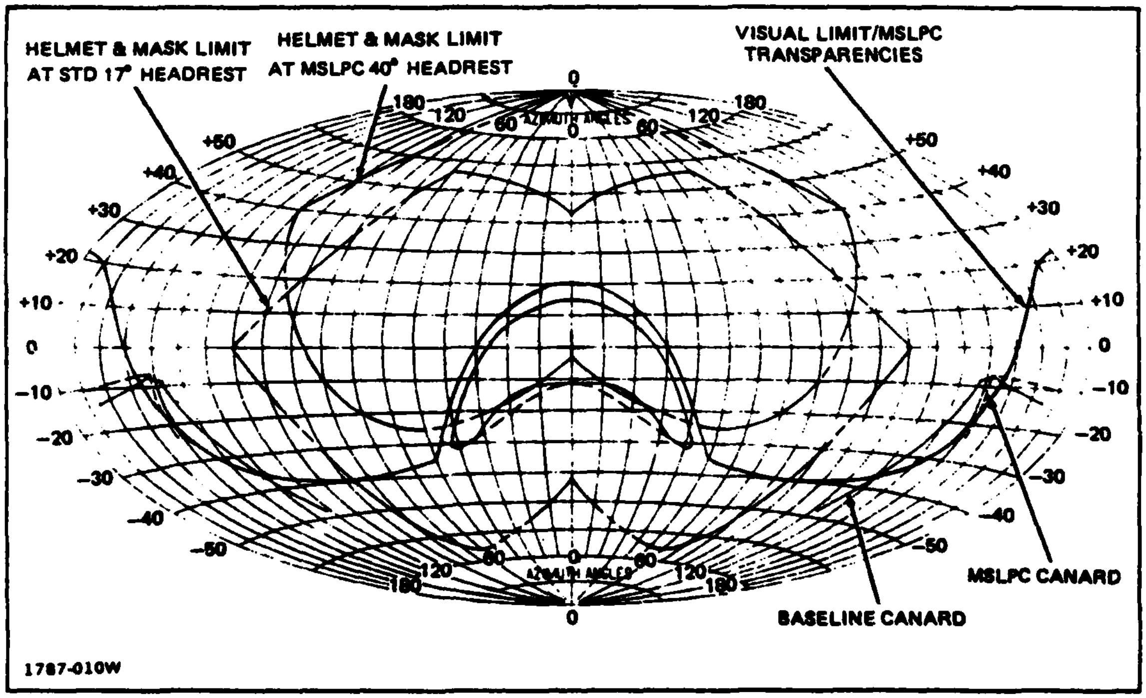


Figure 2-8. MSLPC Vision Plot

helmet being in continuous supporting contact with the 40° head rest. The line of sight for the visibility area of the MSLPC geometry, therefore, is 40° in elevation. The helmet and oxygen mask limitations, as defined by AFFDL-TR-74-48 (Ref. 2), are plotted for both STD and MSLPC head positions.

2.4.4 MSLPC Implications

The elevation of the static area of visibility produces mixed results. The 28 % increase in external visibility, as measured on the Aitoff's equal area plot, complements the improved G tolerance and contributes to an enhanced air-to-air fighter capability. Aft visibility is not restricted beyond that of a conventional ejection seat equipped cockpit, except that a more demanding physical effort is necessary to lift and/or rotate the head. However, internal visibility is severely constrained. Visual access to the instrument panel and side quarter panels is possible only by changing the head position.

Further investigation of an adjustable headrest/support appears necessary to resolve the specific visibility requirements with respect to external takeoff/landing conditions and internal instrument panel/side console surfaces. A closer examination of the physiological constraints, including the problem of ejection acceleration limits associated with the flexed spine, is also in order.

2.5 MSLPC CREW STATION VARIATIONS

Variations in the MSLPC baseline were examined in order to determine the absolute minimum sized low profile cockpit. If size is measured in terms of overall height (from canopy to floor), then contributing factors are:

- Head clearance radius
- Head rest and back rest angles
- Elbow clearance
- Side console height
- Forward down vision.

The MSLPC baseline configuration has a standard 10-inch head clearance radius, a 40° headrest, a 65° back rest, clearance for a 95th percentile elbow, a standard 8-inch high side console, and 11° forward down vision. The optimal floor level is determined by the limit to which feet and rudder pedals can be raised before interference with aircraft structure. Forward down vision becomes a factor in determining overall MSLPC height in as much as it limits the

aircraft contour lines forward of the windshield and, indirectly, fixes the foot interference level.

The MSLPC alternate configuration (Figure 2-9) incorporates a number of variations which reflect a further reduction in cockpit size. The head clearance radius is reduced to 8 inches because the head and upper torso will be relatively immobile and a distinct effort would be necessary to raise the head off the headrest. Head motion would be limited to turning or rolling to gain visual access to the side. Because of the advances in solid state electronic technologies, console control panel sizes could be (and are) appreciably smaller than the standard dimensions. Actually, an optimal floor location is determined by the limit to which the feet and rudder pedals can be raised before interference with aircraft structure. The floor of the MSLPC alternate configuration was accordingly raised 2.5 inches which resulted in 5.5-inch high side consoles.

The combined reduction of eye-to-floor height and head clearance results in an overall canopy-to-floor height of 38.5 inches. The corresponding cross sectional area at the design eye station is reduced from 9.4 ft^2 to 8.2 ft^2. During the exploration of variations, an adjustable backrest was considered. Pending final resolution of escape system propulsion elements, the MSLPC baseline configuration has space below the seat which could be used to accommodate additional adjustment of the backrest. The adjustment could be variable or permanent; i.e., variable in that the backrest angle could be changed in flight or permanent in that the backrest angle is functionally optimized and fixed. If permanent (fixed), the angle would complement structural G limits (maneuverability) and, if less that 65°, the configuration would benefit from increased instrument panel area (lower knee clearance). If variable, the adjustability would provide an inflight comfort control during particular phases of the mission.

The physical aspects of the baseline MSLPC were substantiated using the Grumman Advance Cockpit Mockup Facility. Modular construction of the principal cockpit elements such as the instrument panel, control consoles, windshield frames, canopy bows, and ejection seat make it possible to expeditiously incorporate conceptual alterations in the facility. In addition to incorporation of representative MSLPC baseline seat geometry, side consoles, flight controller, and throttle assembly, the mock-up modification (Figure 2-10) features a hinged and separable windshield/instrument panel assembly, interchangeable

COMPARISON

ITEM	BASELINE	MSLPC VARIATION
1	43.0	38.5
2	10.0 R	8.0 R
3	8.0	5.5
4	10.5	8.0
5	5.0	4.75
6	9.0	7.5
7	27.5	25.25

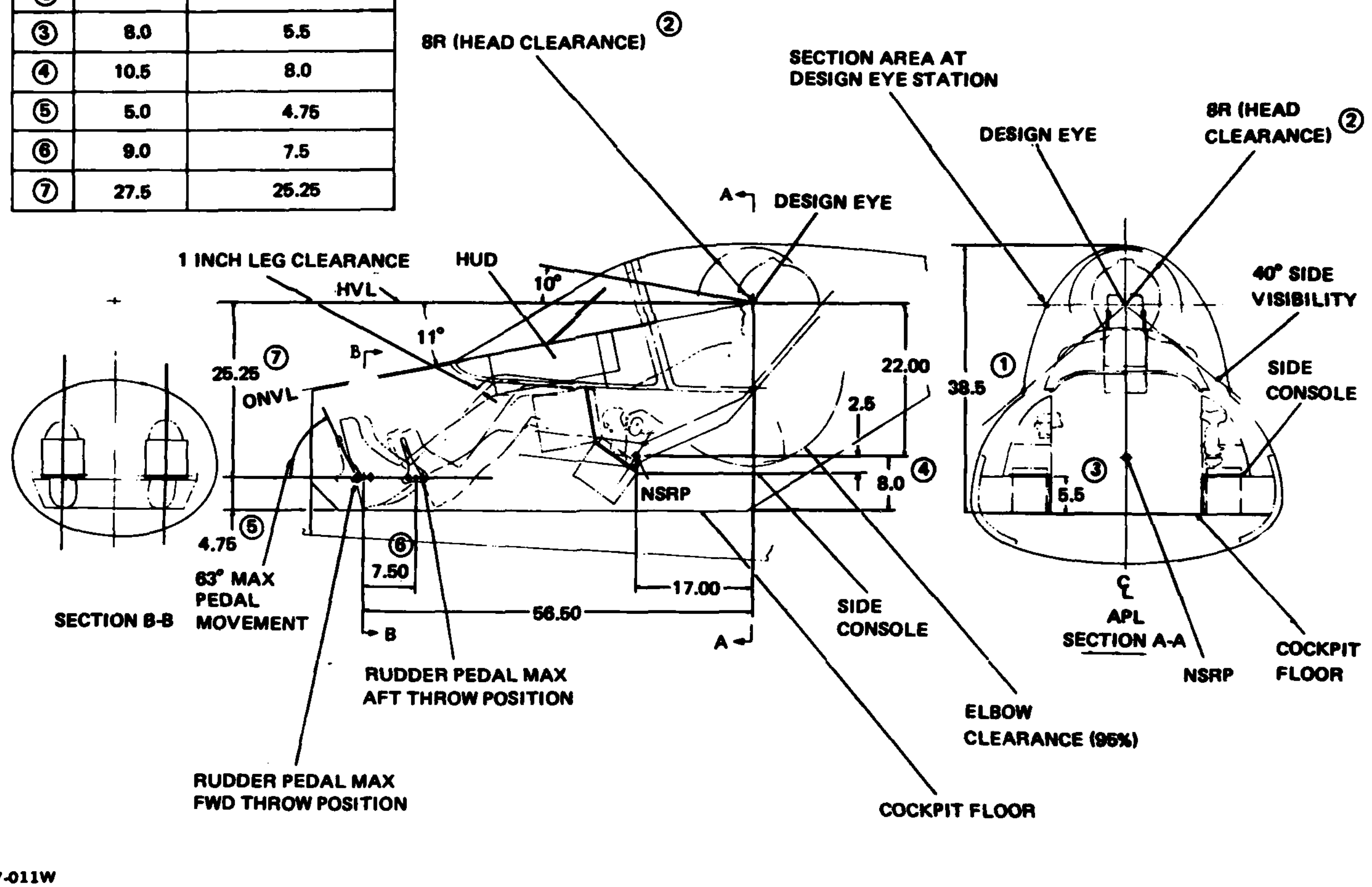


Figure 2-9. MSLPC Alternate Configuration

Figure 2-10. MSLPC Mock-up

8-inch and 10-inch head clearance canopy constraints, and an adjustable headrest (17° to 65°). Although an adjustable headrest would add to the weight and complexity of the escape system, benefits can be derived from a subsystem which would permit manual positioning forward, and would automatically position the headrest aft as part of the pre-ejection functions; such as:

- Improved visual access to side consoles
- Potential enhancement of takeoff and landing visibility
- Increased windblast protection on separation
- Elimination of flexed spine on ejection.

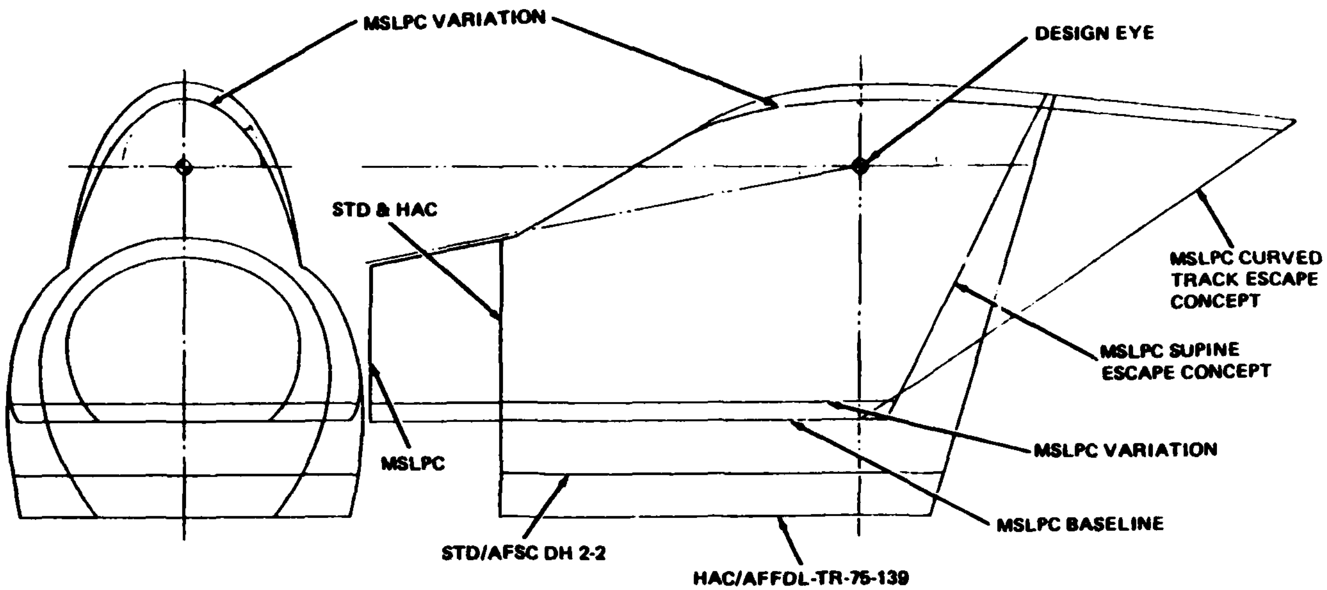
In addition to confirmation of the MSLPC baseline geometry, the mock-up made a significant contribution to the resolution of the ingress/egress problem

and the selection of the preferred escape system concept to be discussed in the following sections. Within the context of the MSLPC configuration and crew escape integration study, the mock-up evaluation also revealed the following:

- Flight and propulsion control locations and displacements were acceptable
- All control panel surfaces were within operational reach
- Forward adjustment of the headrest appears necessary to optimize forward vision for landing.
- Visual access to the side console control surfaces is severely limited by the pilot's torso in the semi-supine position.

2.5.1 Crew Station Sizing Summary

In order to place the beneficial form-factor of the MSLPC in proper perspective, a comparison to other crew station concepts is presented in Figure 2-11. Both the "standard" crew station defined by AFSC DH 2-2 and the HAC applied to the F-15 crew station (AFFDL-TR-75-139) are included, as well as the baseline MSLPC and the variations MSLPC. Cockpit size data were generated through the use of a graphics data tablet (DATAB) oriented computer program which is capable of extracting various information from drawings and layouts. The MSLPC configurations reflect an added difference in size that results from the application of particular escape system concepts which are discussed in following sections.



COCKPIT TYPE	PROFILE AREA, FT^2	SECTION AREA AT D.E., FT^2	HEIGHT AT D.E., IN.	PRESSURE VOLUME, FT^3	SURFACE AREA, FT^2
STD/AFSC DH2-2	19.7	11.6	50.0	51.6	79.2
HAC/AFFDL-TR-76-139	21.8	13.2	55.5	57.8	82.2
MSLPC-BASELINE					
SUPINE	17.8	9.4	43.0	42.6	75.8
CURVED TRACK	22.5	9.4	43.0	51.6	85.4
MSLPC-VARIATION					
SUPINE	16.3	8.2	38.5	38.2	73.6
CURVED TRACK	20.6	8.2	38.5	47.6	82.4

1787-013W

Figure 2-11. Cockpit Sizing Parameters

III. ESCAPE SYSTEM CONCEPTS

An initial population of candidate open escape system concepts was postulated consistent with the unique integration imperatives of the MSLPC. Although the use of a separable nose capsule would provide a relatively well established escape system capability, inconsistency with the minimum cost and complexity goals of the MSLPC program preclude its selection as a candidate. The investigation is focused on the development of variations of the ejection seat escape concept which provides an escape capability (within the guidelines of MIL-S-9479B) in the following critical areas:

- High speed conditions up to 687 KEAS/1600 PSF dynamic pressure
- High acceleration environment
- Low altitude and adverse attitude.

The investigation initially identifies and describes the candidate escape system concepts, complemented by a discussion of distinctive features, advantages, and disadvantages. An evaluation of human factors was made to determine the magnitude and direction of acceleration forces generated during the catapult or boost phase of the escape sequence. Weight and mass properties of the seat/man mass were established for the determination of computer simulated aerodynamic performance and aircraft configuration tradeoffs.

3.1 CANDIDATE ESCAPE CONCEPTS

The escape system concepts were conceived with attention to pilot safety and survival, including system initiation, pilot restraint, aircraft separation, tail clearance, stabilization, system sequencing, recovery, crash conditions, emergency rescue, and normal ingress/egress.

The escape system concept consistent with the MSLPC geometry appears to provide some potential benefits. Possible advantages include the directing of ejection forces along a more favorable body axis (eyeballs-in, instead of eyeballs-down), and the reduction of high speed drag and deceleration forces as a result of smaller frontal areas on separation. However, there are also possible disadvantages including pilot restraint in a large seat pan/backrest angle (148°)

under deceleration forces, larger cockpit volume resulting from ejection clearance requirements, and an increase in cockpit complexity to facilitate seat/man separation from the aircraft. The escape system concepts derived and examined in this investigation exhibit these advantages and disadvantages in varying degrees.

Escape from the MSLPC is analogous to removing a foot from a shoe. The initial ejection system constraints assumed that all aircraft or crew station elements (windshield, instrument panel) not essential to implement the escape function for a particular escape concept would remain intact. The separation of the seat/man mass from the aircraft accordingly followed a predominantly aft direction of travel. Subsequent examination, however, revealed possible system advantages in enlarging the escape clearance envelope by moving or jettisoning the windshield and instrument panel to permit the separation of the seat/man mass in a more upward direction. The candidate escape system concepts therefore included:

- Deflection Wedge - Upright
- Deflection Wedge - Recline
- Tractor Rocket
- Shield/Canopy
- "B" Seat Variant
- Curved Track
- Supine Concept.

With the exception of the tractor rocket concept, the escape systems initially conceived generally conform to the following description.

The primary system activation (ejection) control grips are located on each side of the seat pan structure, operable with either or both hands. System activation instantaneously initiates seat catapult and body restraint functions. Lower limb restraint or retraction is time delayed when necessary to clear aircraft structure. The seat catapult consists of dual thrusters attached to the back of the seat and forming an integral part of seat structure. Dual manifolds provide gas pressure which initiates catapult cartridge firing. A mechanical guidance system controls the movement of the seat/man mass from the base of the cockpit to an aircraft separation position and an attitude predetermined by flight simulation and analysis. A rocket motor, whose thrust/time profile is determined by flight simulation and analysis, is located on centerline within the backrest cavity and vectored through the center-of-gravity (CG) of the seat/man mass. Ignition is programmed for some point in time during track guidance prior to aircraft separation. During free flight, separation of the man from the seat is programmed to occur at acceptable G levels. The crewman is extracted from

the seat by the parachute. Parachutes are stowed in the headrest and the backrest cavity. The survival kit is located in the seat pan cavity.

The differences and variations manifest in each particular escape system concept are described in the following subsections. The event time sequence for each concept is shown in Table 3-1.

3.1.1 Deflection Wedge - Upright

Both the upright (Figure 3-1) and reclined (Figure 3-2) deflection wedge concepts feature an extendible boom and wedge located on centerline below the

TABLE 3-1. ESCAPE CONCEPT EVENT-TIME SEQUENCE

(Ground Level, 600 KEAS)

ESCAPE SEQUENCE/EVENT	TIME AFTER INITIATION, SEC					
	DEFLECT. WEDGE	TRACTOR ROCKET	SHIELD CANOPY	"B" SEAT	CURVED TRACK	SUPINE CONCEPT
SYSTEM INITIATION	0	0	0	0	0	0
AUTO RESTRAINT	0	0	0	0	0	0
CANOPY JETTISON	0	0	NONE	0	0	0
SEAT BOOST/CATAPULT	0.3	0.3	0	0.3	0.3	0.3
WEDGE EXTENSION	0.45	NONE	NONE	NONE	NONE	NONE
SEAT RELEASE (TOP OF BOOST)	0.50	0.50	0.15	1.5	0.50	0.5
CANOPY THRUSTERS	–	–	0.15	–	–	0
ROCKET THRUST-START	0.51	0.51	0.21	1.51	0.51	0.51
ROCKET BURN OUT	0.76	1.01	2.41	2.01	2.51	2.51
DROGUE SLUG FIRING	NONE	–	2.01	3.5	2.00	2.00
DROGUE LINE STRETCH	NONE	0.9	2.30	3.7	2.3	2.3
DROGUE INFLATED	NONE	1.15	2.40	4.00	2.40	2.4
DROGUE STAGING (FIRST)	NONE	0.9	NONE	NONE	–	–
DROGUE STAGING (SECOND)	NONE	1.0	NONE	NONE	–	–
DROGUE RELEASE	NONE	1.4	4.10	6.80	3.85	3.85
PARACHUTE DEPLOY	1.75	1.4	4.10	6.80	3.85	3.85
PARACHUTE LINE STRETCH	2.50	3.3	4.80	7.50	4.60	4.6
PARACHUTE FIRST OPEN	2.60	4.3	4.90	7.60	4.70	4.7
PARACHUTE FINAL OPEN	2.75	4.5	5.30	8.00	5.10	5.1
PARACHUTE VERTICAL	–	–	–	8.80	–	–
GROUND CONTACT	6.75	5.3	9.00	11.00	8.00	8.0
1787-014W						

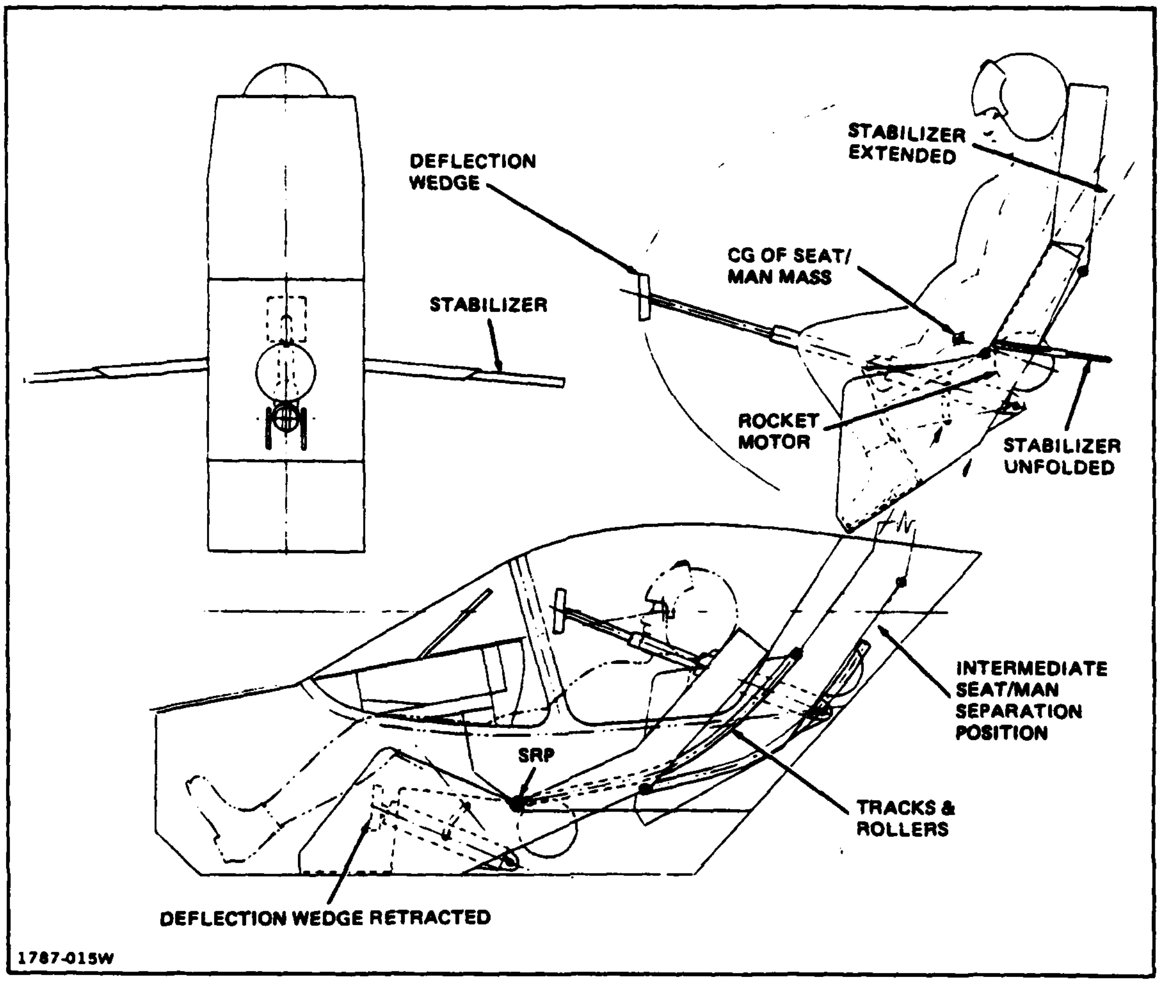


Figure 3-1. Deflection Wedge - Upright Concept

seat pan. Activation of boom extension is programmed for clearing the windshield bow. Fully extended, the wedge creates a protective air envelope by deflecting the air blast. The protective envelope has a lower drag profile which results in a lower rate of deceleration and, therefore, lower G loads on the man. Dual aerodynamic control surfaces, stowed on the sides of the seat, are extended at the time of aircraft separation for stabilization of the seat/man mass. The weight of the wedge contributes to improved pitch stability by moving the CG of the seat/man mass forward.

The deflection wedge - upright concept was initially considered to have good potential as a solution to the high speed air blast problem, and incorporates a curve track variation to move the seat/man mass from normal reclined position (65°) to an upright separation position (34°). Extraction from under the instru-

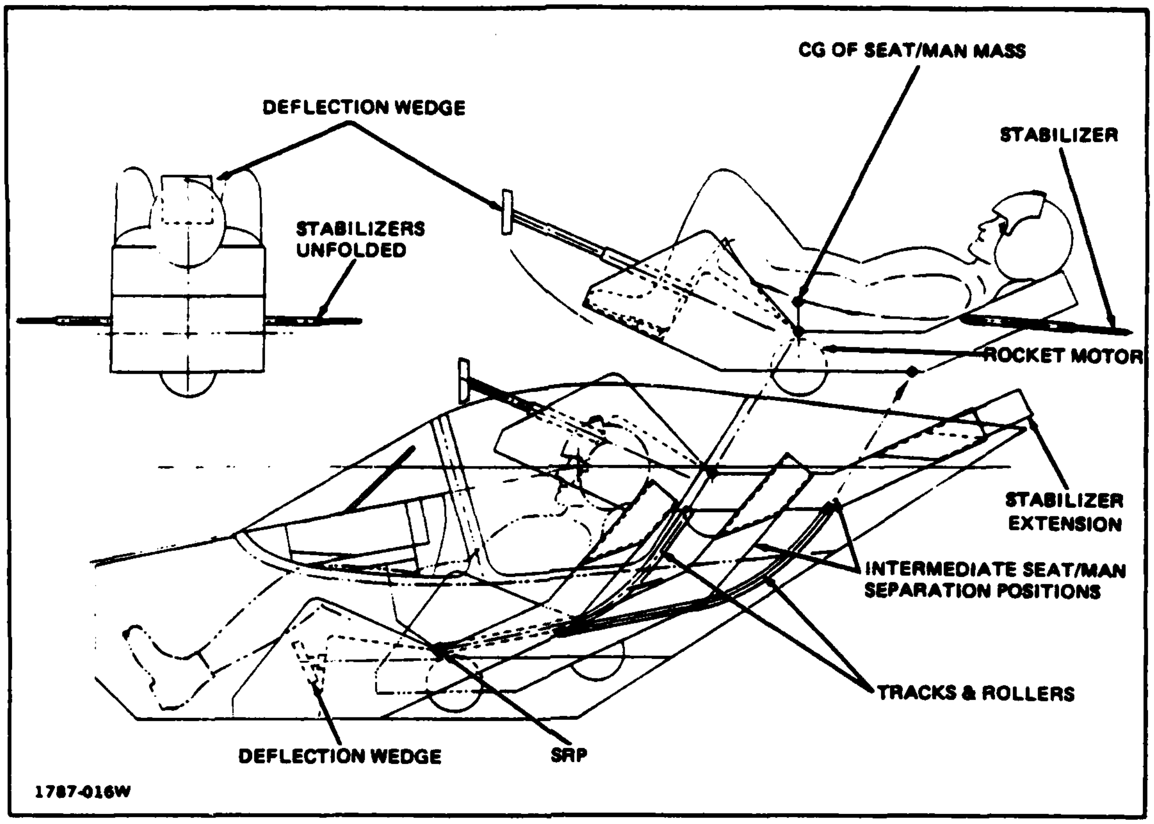


Figure 3-2. Deflection Wedge - Recline Concept

ment panel is facilitated and pressurized cockpit volume is minimized by the aft varying upward transition. Although G levels are tolerable during the transition, entrance to the air stream is accompanied by high deceleration G (eyeballs-out) resulting from the large frontal area (6.6 ft^2) of this concept. The need for ballast in the wedge and the acceptability of deployable wings for stabilization is subject to further investigation with respect to the application of drogue chutes and/or thrust vector control. In addition to projected pitch and yaw stability problems, the combined size, weight, and complexity imposed by the extendible wedge and stabilizer present a significant penalty.

3.1.2 Deflection Wedge - Recline

In this concept, the seat/man is moved from the normal reclined (65°) position to an aircraft separation (4°) position, resulting in a larger cockpit because of the predominantly aft direction of the seat/man boost. The rotational force imposed by this transition will apply a moderate bending moment to the catapult/track subsystem. The G levels are tolerable during the transition and entrance to the air stream produces deceleration G (eyeballs-down) minimized by the

small frontal area (4.1 ft^2). Adequate restraint and soft tissue injury prevention after separation are considered difficult tasks. The comments on the deflection wedge - upright concept, regarding the wedge and stabilizer, also apply to the recline concept.

3.1.3 Tractor Rocket

An independent rocket motor installation, including the motor, a catapult mechanism, and pendant line interface, is located on the aircraft centerline aft of the seat headrest (Figure 3-3). The initiation of rocket motor catapult precedes the seat catapult initiation. Pendant lines are routed (stowed) to ensure clear deployment on separation of rocket from the aircraft and the seat.

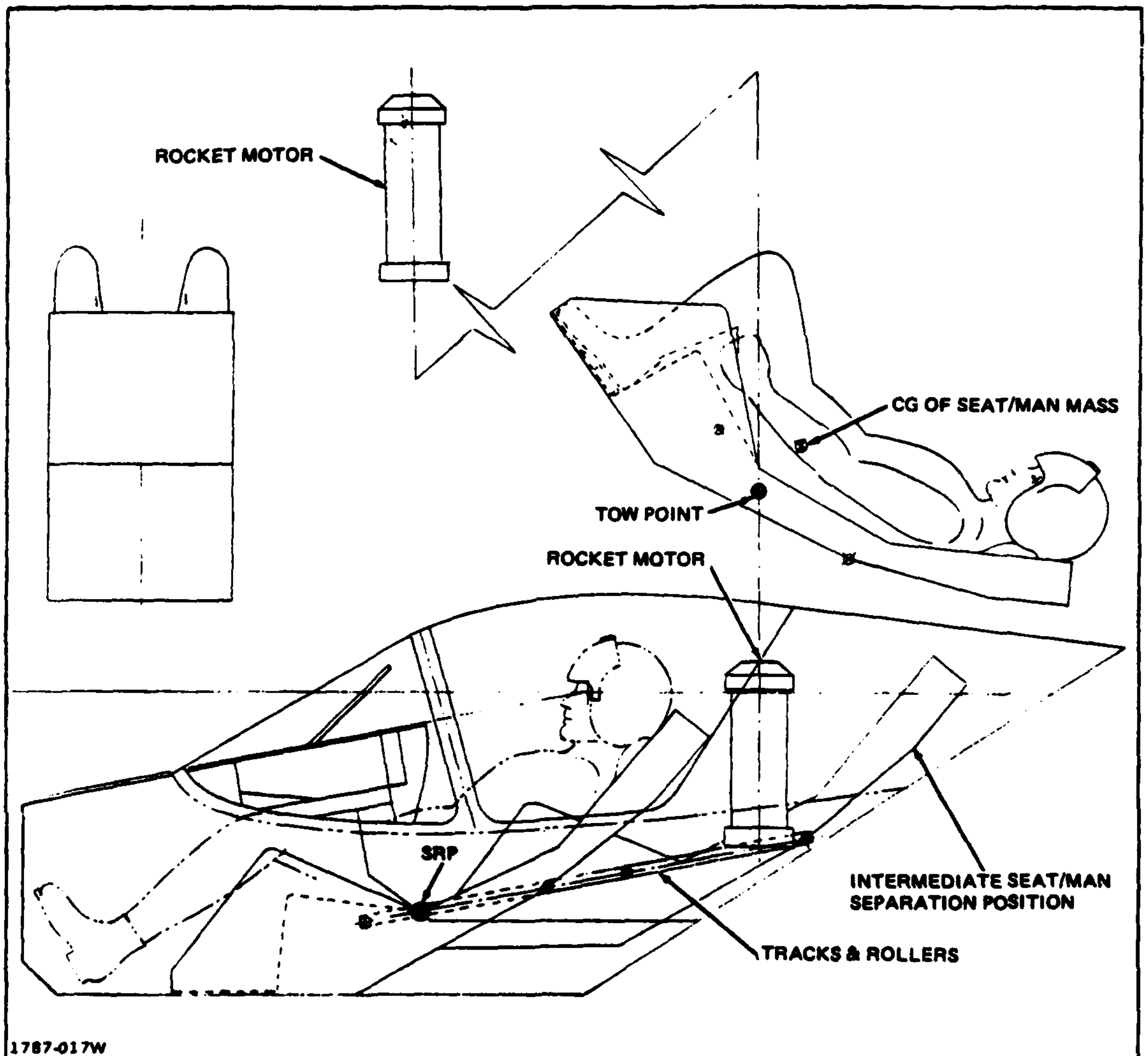


Figure 3-3. Tractor Rocket Concept

The principal claims for rocket extraction systems are: low mass, low initial pilot acceleration, and inherent stability of the man trailing behind the tractor rocket. Because the extracted mass is lower than that of a conventional seat, it may also be argued that limb flailing is reduced. However, when applied to a pilot in a reclined seating posture, many of these advantages are likely to disappear.

If the initial loads are maintained at the levels claimed for existing extractor systems and are applied in line with the seat back, it is almost inevitable that the extracted man will impact the aircraft vertical fin. To gain an acceptable trajectory would require the initial rocket force to be applied almost normal to the seat back. With a long arm between the center of mass of the man and the line of action of the force, very high pitching acceleration would be produced. Apart from the harmful physiological effects such rotations may have on the man, there is also likely to be interference between the man and the cockpit structure during separation.

In addition, the stability of the tractor deteriorates at speeds above 350 knots, making achievement of a satisfactory trajectory difficult and uncertain. Coupled with the possibility of aircraft roll at the time of separation, the extraction force could develop a lateral component.

3.1.4 Shield/Canopy

System activation initiates seat catapult and body/limb restraint functions. The track and roller system guides the seat to an interface/interlock position parallel to the canopy longeron (sill). Fairing panels are deployed or inflated between the sides of the seat and the longerons (Figure 3-4). A windshield/canopy/seat interlock is activated and shield/canopy jettison is initiated. Inflation of a fairing panel between the windshield and the seat coincides with aircraft (glareshield) clearance. Stabilization is achieved by an attitude sensing system which transmits vector correction signals to a gimballed rocket motor. Primary stabilization is supplemented with the programmed deployment of a drogue parachute. Shield/canopy - seat/man separation precedes seat-man separation and is initiated under drogue influence.

The shield/canopy concept incorporates features that enhance high speed escape. The seat/man mass is moved from the normal reclined (65°) position to an interface position parallel to the canopy longeron (0°) for engagement and interlock. The transition continues through ballistic severance of windshield/

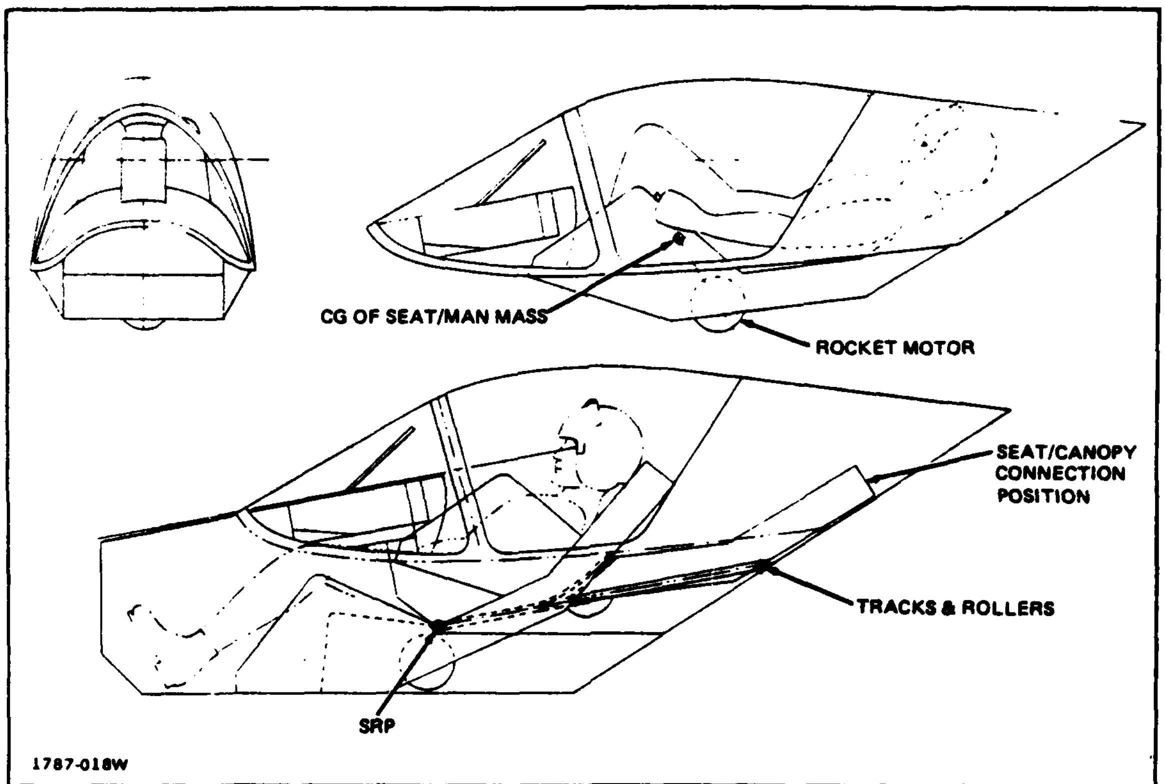


Figure 3-4. Shield/Canopy Concept

canopy to a nose-up position (20°) for final separation from the aircraft. The shield/canopy provides wind blast protection which eliminates the limb flail problem. The configuration resulting from the integration of the seat, canopy, and windshield minimizes the magnitude of deceleration forces and facilitates tail clearance. The disadvantages, however, are significant. The integration of the seat, windshield, canopy, and closure fairing as an ejectable assembly makes this concept extremely complex and heavy. The drogue parachute system requires additional staging to implement separation of canopy and seat and subsequently seat and man. Forceful separation may be necessary to preclude injury to the pilot. The time delays involved in positioning the pilot, forming the seat/shield/canopy assembly, and subsequently extracting the pilot from the seat/shield/canopy seriously compromise the low altitude/adverse attitude capability.

3.1.5 "B" Seat Variant

Lower limb restraint or retraction is time delayed to clear the instrument panel, and coincides with the inflation of a nose cone enveloping the forward end of the seat (Figure 3-5). Stabilization is provided by the tailboom assembly con-

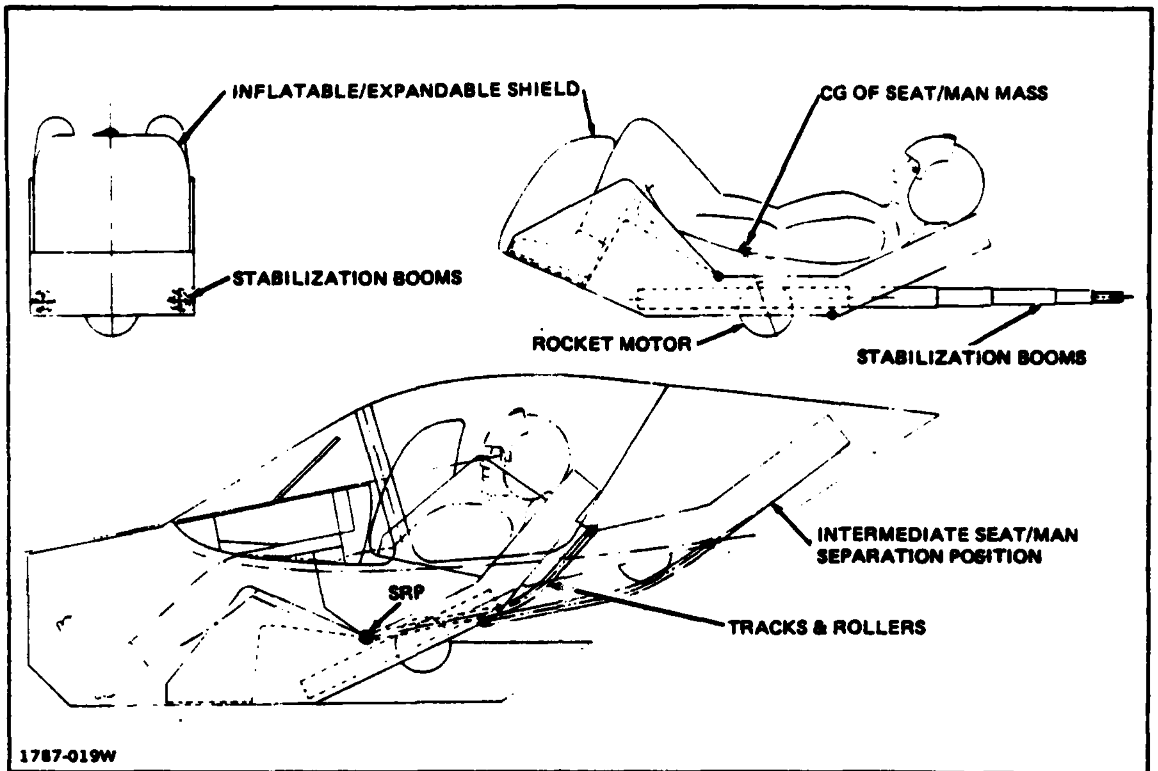


Figure 3-6. "B" Seat Variant Concept

sisting of two tubular telescoping sections located in the outboard corners of the backrest support structure. Extension of the booms is programmed for aircraft clearance. A drogue parachute supplements primary stabilization and implements seat-man separation.

The "B" seat variant concept uses a protective windblast shield and extendible booms for inflight stabilization. The seat/man mass is moved from the normal reclined (65°) position to the separation (0°) position. During the transition, the lower limbs are retracted and the windblast shield deployed. The blast shield constrains the lower limbs to the center of the seat and, on separation from the aircraft, diverts the air stream. Deployment of the stabilization booms must occur at a critical point in the escape sequence in as much as both seat/man mass attitude control and tail clearance are conflicting requirements. The substitution of an inflatable aft fairing for the stabilization booms, which would reduce complexity with some added risk, appears to merit further consideration.

3.1.6 Curved Track

The system conforms to the previous general description except that stabilization is achieved by an attitude sensing device that transmits vector correction

signals to a gimballed rocket motor (Figure 3-6). A drogue parachute supplements primary stabilization and implements seat-man separation.

This concept moves the seat/man mass from the normal recline (65°) to the separation (0°) position, without interference with the instrument panel or any other part of the cockpit, after canopy jettison. The cockpit is sized to accommodate the aft/upward direction traversed. The rotational force imposed by this transition will apply a moderate bending moment to the catapult/track subsystem. Tolerable G levels are expected during the transition, and entrance to the airstream is accompanied by minimal deceleration G (eyeballs-down) resulting from the small frontal area (3.8 ft^2).

3.1.7 Supine Concept

Several variations of the supine concept were configured and evaluated. The variations (Figure 3-7) are reflected in the disposition of the windshield and instrument panel assembly and the seat/man mass. They are identified as: the hinged windshield/panel; the tracked windshield/panel; and, the jettison windshield/ panel. The variations were evaluated (Table 3-2) in terms of weight, volume, and complexity, with lowest score indicating preferred variation.

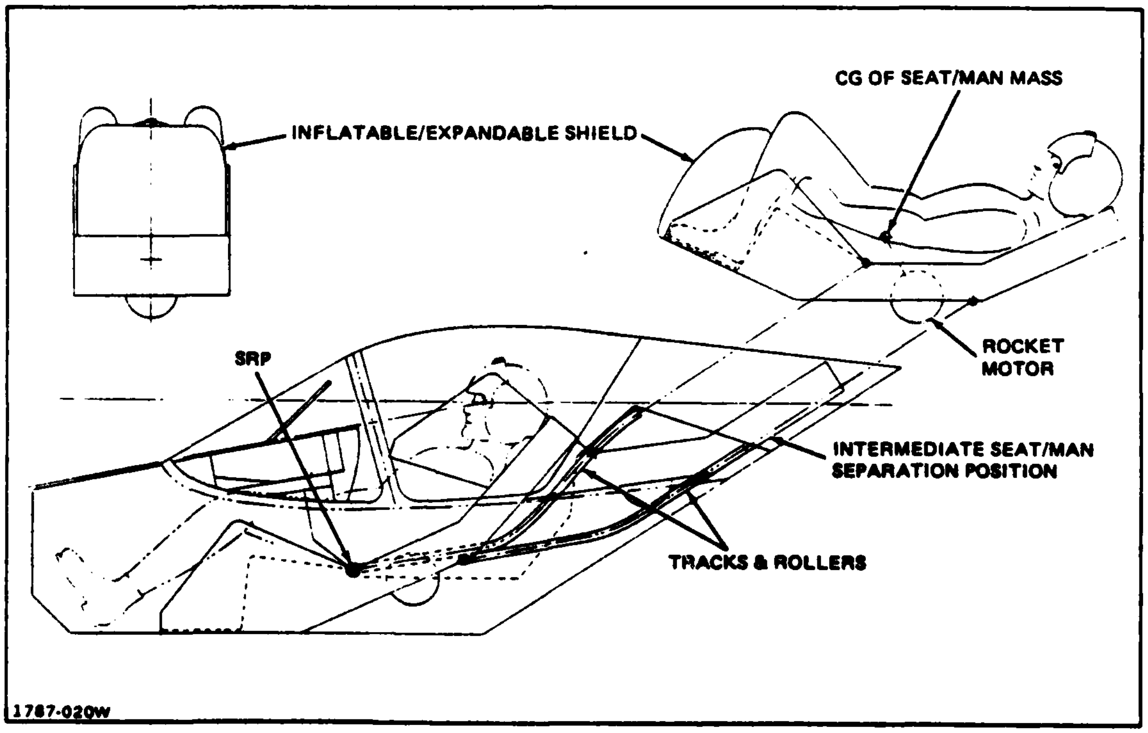


Figure 3-8. Curved Track Concept

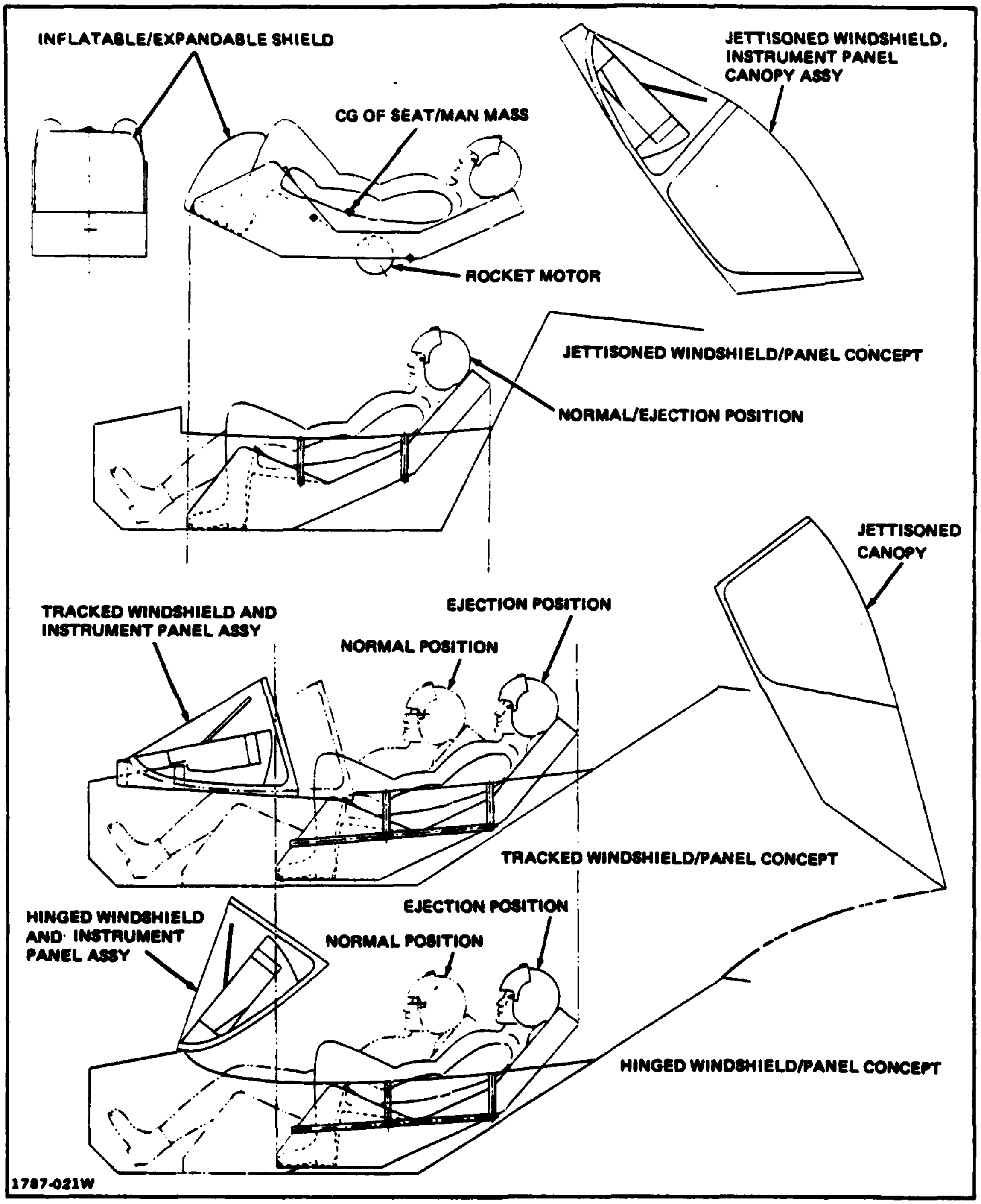


Figure 3-7. Supine Concept

TABLE 3-2. CONCEPT EVALUATION (Rating: 1 = Excellent; 2 = Good; 3 = Fair; 4 = Poor)

FACTOR	HINGED WINDSHIELD & PANEL	TRACKED WINDSHIELD & PANEL	JETTISON WINDSHIELD & PANEL
WEIGHT	2	3	2
VOLUME	2	2	1
COMPLEXITY	2	3	1
TOTAL	6	8	4

1787-022W

The primary activation control for the jettison windshield/panel concept instantaneously initiates canopy/bow interlock, instrument panel services guillotine, and body/limb restraint functions. The windshield, instrument panel, and canopy are jettisoned and the seat catapult positions the seat/man mass for separation and free flight. Stabilization is achieved by an attitude sensing device which transmits vector correction signals to a gimballed rocket motor. Other system features are consistent with the previous general description.

This concept moves the seat/man mass directly upward with no aft motion. A small rotational change (25° to 0°) to attain the optimum aircraft separation attitude is required as the windshield/canopy/instrument panel are jettisoned. Since ejection forces are applied normal to the fully supported spine, higher accelerations are possible without injury to the crew, thereby reducing recovery time. Development would be expensive, although significant increase in G tolerance could be achieved.

3.2 HUMAN FACTORS

The acceleration environment experienced by the pilot, prior to separation from the aircraft, is generated by the catapult force and track path on initiation of escape. The condition varies with respect to the unique design features of each particular escape system. Since the catapults are not sized at this point in the study, the effect of acceleration forces on the pilot is indeterminate.

On separation from the aircraft, high speed wind blast causes differential drag forces which induce relative motion of limbs and torso, resulting in flail injury when inadequate protection and restraint is provided. The MSLPC escape concepts feature inflatable elements for protection, restraint, and/or containment to minimize susceptibility to flail injury. The time, thrust, and attitude variables applied for free flight analysis have a direct affect on acceleration force vectors and, therefore, the physiological acceptability of the free flight environment is addressed in the escape concept analysis presented in Section IV.

In all escape concepts, the pilot is adversely affected during crash conditions. The recline angle subjects the pilot to spinal (eyeballs-down) accelerations which are not contained by the seat pan.

3.3 AIR VEHICLE INTERFACE

The variations in the candidate escape system concepts impose significant differences in the air vehicle interface. The sizing and configuration of a cockpit to accommodate a particular emergency escape concept and the incorporation of provisions for normal ingress/egress are not necessarily complementing requirements.

3.3.1 Cockpit Size

The size of the cockpit pressurized volume is directly related to the path followed by the seat/man mass in separating from the aircraft. The rearward path of the curved track concept results in a long cockpit with a large volume, and the upward path of the supine concept results in a short cockpit with a small volume (Figure 3-8). A comparison of significant sizing parameters for the candidate escape concepts is shown in Table 3-3.

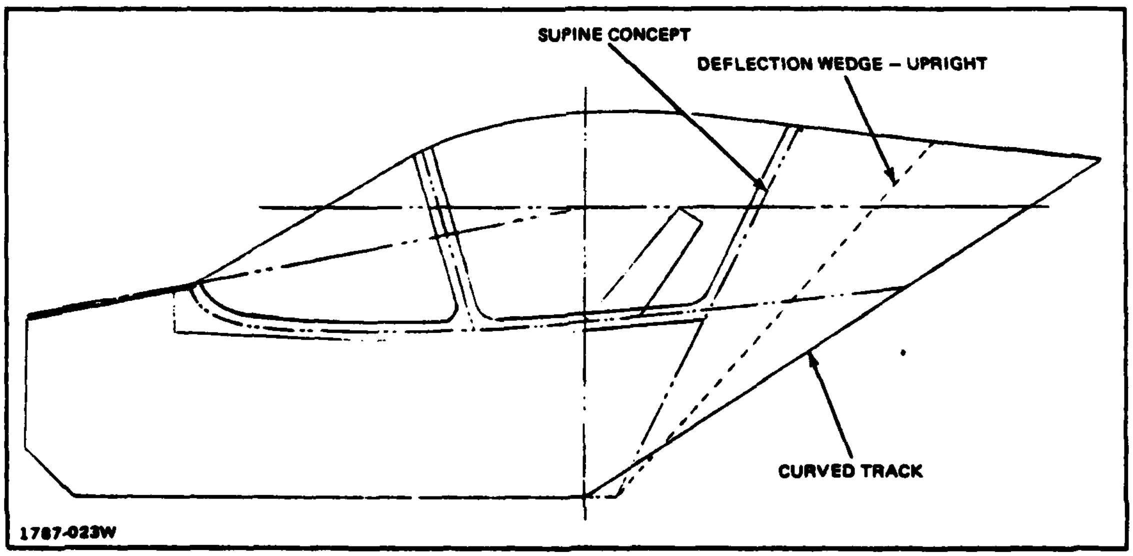


Figure 3-8. Escape Concept Impact on Cockpit Size

TABLE 3-3. COCKPIT SIZE DATA

ESCAPE CONCEPT	VOLUME, FT^3	PROFILE AREA, FT^2	SURFACE AREA, FT^2
DEFLECTION WEDGE-UPRIGHT	46.6	20.1	79.2
DEFLECTION WEDGE-RECLINE	51.6	22.5	85.4
TRACTOR ROCKET	51.6	22.5	85.4
SHIELD/CANOPY	51.6	22.5	85.4
"B" SEAT VARIANT	51.6	22.5	85.4
CURVED TRACK	51.6	22.5	85.4
SUPINE CONCEPT	42.6	17.8	75.8
1787-024W			

3.3.2 Ingress/Egress

Ingress/egress for the MSLPC would be extremely difficult without some integral aid mechanism. The problem is essentially one of moving the pilot out from under the instrument panel or moving the instrument panel away from the pilot. In any case, effective solutions are dependent upon compatibility with the unique features of a particular escape concept. For example, ingress/egress for the curved track concept would take advantage of the existing track and roller system, and independently drive the seat aft to a position which permits knee clearance with respect to the instrument panel (Figure 3-9). Ingress/egress for the supine concept would be facilitated by a forward hinged windshield canopy, and instrument panel assembly that is raised sufficiently to provide knee clearance. In both examples, the pilot would then slide over the sill with the assistance of hand grips. Selection of the procedure and implementation of ingress/egress for MSLPC is deferred to the selection of a preferred escape system concept.

3.4 WEIGHT AND MASS PROPERTIES

The CG and moments-of-inertia (M of I) for each escape concept (Table 3-4) are established for the seat/man mass situated at aircraft separation in a free flight environment with the seat back tangent line parallel to the aircraft longitudinal axis (Appendix A). A baseline seat/man system was established to provide a standard for evaluating the MSLPC escape concepts. In addition, a systematic means to adjust the crew weight and furnishings and equipment parameters in the Computerized Initial Sizing Estimate (CISE) program was de-

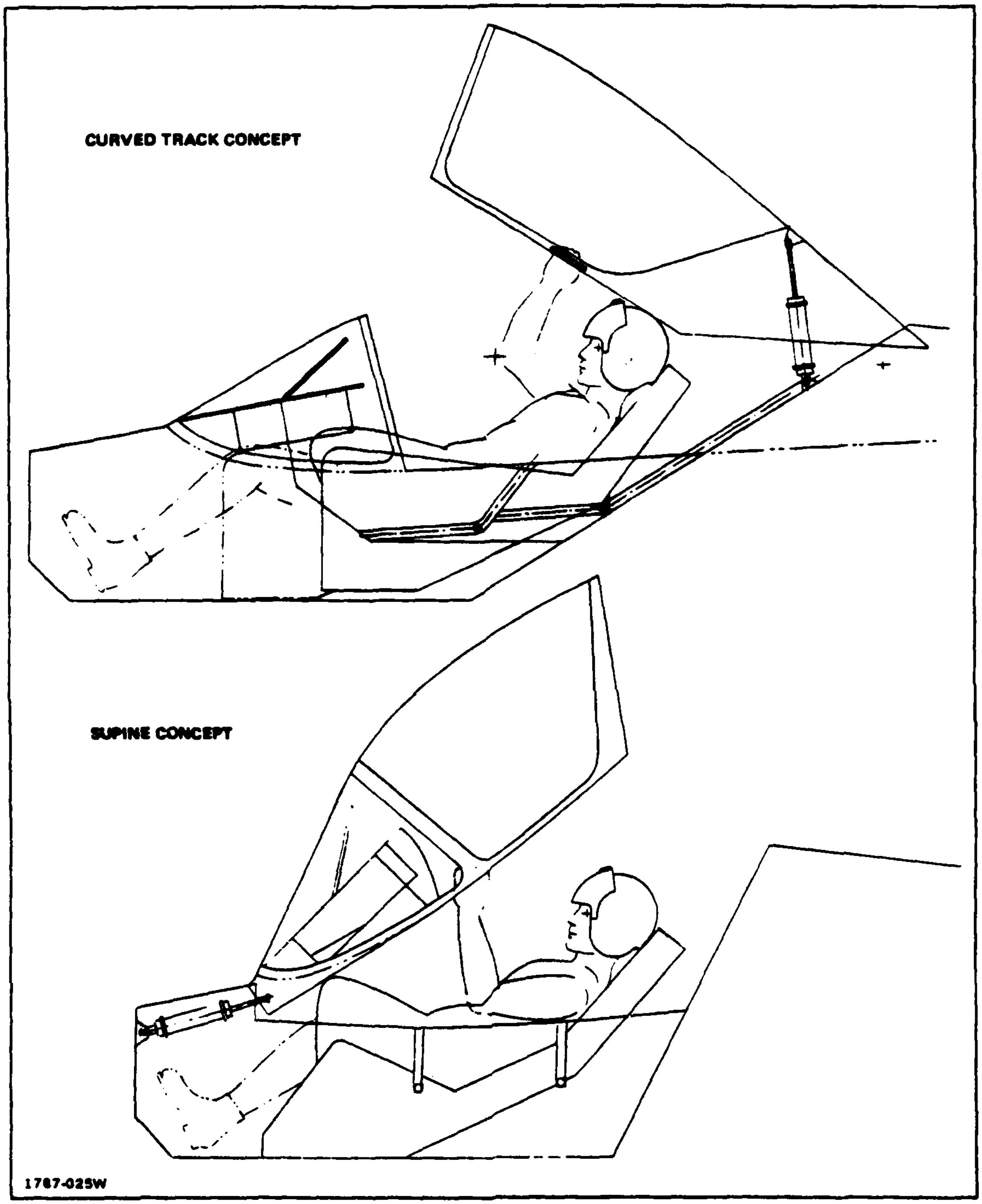


Figure 3-9. MSLPC Ingress/Egress

TABLE 3-4. WEIGHT AND MASS PROPERTIES (95th Percentile Pilot)

ESCAPE CONCEPT	EJECTED WT, LB	CG		M OF I (SLUG FT^2)			
		X	Z	XX	YY	ZZ	XZ
DEFLECTION WEDGE (U)	523.0	–	–	–	–	–	–
DEFLECTION WEDGE (R)	523.0	–0.3	3.8	6.99	30.89	30.73	–1.04
TRACTOR ROCKET	493.8	2.6	4.4	6.42	24.00	25.04	–0.70
"B" SEAT VARIANT	505.9	3.5	3.8	6.75	27.68	27.98	–1.53
CURVED TRACK	487.3	2.6	3.8	6.80	24.23	24.54	–0.53
SHIELD/CANOPY	609.0	2.1	5.8	15.31	58.96	58.84	0.18
SUPINE CONCEPT	487.3	2.6	3.8	6.80	24.23	24.54	–0.53
1787-026W							

rived to ensure consistency within the aircraft configuration estimates and candidate escape system comparison. The CISE program (refer to Section V) is a computerized methodology employed as a sizing and screening process, and a rapid procedure for conducting trade studies.

3.4.1 MSLPC Baseline Escape System Weight

Since the most critical weight is the 95th percentile crewman with winter clothing and equipment (Appendix A), the baseline was configured to reflect these weights. A baseline escape system weight summary was established as follows:

Crew Weight, Lb		
1-Crew (95th percentile)	210.8	
Personal equipment (Appendix A)	43.2	
Parachute (AFSC-DH-2-1)	25.0	
		279
Furnishings and Equipment Weight, Lb		
Survival Kit (F-15)	38.0	
Seat (F-14)	186.6	
Misc Equipment	53.4	
		278.0
MSLPC Baseline Escape System Weight, Lb		557.0

3.4.2 Derivation of CISE Inputs

The CISE program accounts for total crew station weight in terms of number of crewmen, crew/equipment weight, and furnishings and equipment weight. All concepts have one crewman. Crew/equipment consists of the pilot, parachute, and personal gear. Crew/equipment weight for the MSLPC baseline and other escape system concepts are shown in Table 3-5.

Furnishings and equipment weight (Table 3-6) consists of the seat, survival kit, and miscellaneous equipment such as instrument panels, consoles, and soundproofing. A weight summary for the escape concepts is shown in Table 3-7.

3.5 ESCAPE CONCEPT EVALUATION

The initial evaluation of the escape system concepts involved a ranking (Table 3-8) in terms of aircraft hardware complexity, escape system hardware

TABLE 3-5. CREW/EQUIPMENT WEIGHT, LB

ESCAPE CONCEPT	PILOT, 95%	PARACHUTES	PERSONAL GEAR, 95%	TOTAL
MSLPC BASELINE	210.8	25.0	43.2	279.0
DEFLECTION WEDGES	210.8	20.0	43.2	274.0
TRACTOR ROCKET	210.8	20.0	43.2	274.0
SHIELD/CANOPY	210.8	28.0	43.2	282.0
"B" SEAT VARIANT	210.8	19.0	43.2	273.0
CURVED TRACK	210.8	27.0	43.2	281.0
SUPINE CONCEPT	210.8	27.0	43.2	281.0

1787-027W

TABLE 3-6. FURNISHINGS AND EQUIPMENT WEIGHT, LB

ESCAPE CONCEPT	SEAT	SURVIVAL KIT	MISC EQUIPMENT	TOTAL
MSLPC BASELINE	186.6	38.0	53.4	278.0
DEFLECTION WEDGE	211.0	38.0	53.4	302.4
TRACTOR ROCKET	181.8	38.0	53.4	273.2
SHIELD/CANOPY	174.0	38.0	53.4	265.4
"B" SEAT VARIANT	189.7	43.2*	53.4	286.3
CURVED TRACK	168.3	38.0	53.4	259.7
SUPINE CONCEPT	168.3	38.0	53.4	259.7

*DERIVED FROM CONVAIR REPORT DATA, REFERENCE 9

1787-028W

TABLE 3-7. ESCAPE CONCEPTS WEIGHT SUMMARY, LB

COMPONENTS	MSLPC BASELINE	TRACTOR ROCKET	CURVED TRACK	DEFLECTION WEDGE	SHIELD/ CANOPY	"B" SEAT	SUPINE CONCEPT
SEAT	(186.6)	(181.8)	(168.3)	(211.0)	(174.0)	(189.7)	(168.3)
ROCKET	19.5	22.0	19.5	21.0	21.0	20.5	19.5
PROPELLANT	6.8	6.0	6.5	7.0	12.0	10.5	6.5
SEAT STRUCTURE	119.3	116.8	108.3	94.0	64.0	91.7	108.3
HARNESS RETRACTOR	9.0	5.0	5.0	5.0	5.0	3.0	5.0
HARNESS, BELT, & CUSHIONS	14.0	14.0	14.0	14.0	14.0	14.0	14.0
SEAT MECHANISM	8.0	8.0	8.0	8.0	8.0	8.0	8.0
BOOST INTERFACE	–	–	–	–	40.0	–	–
INIT & SEQUENCING	10.0	10.0	7.0	7.0	10.0	10.0	7.0
STABIL, WEDGE, & BOOM	-	–	–	55.0	–	32.0	–
SURVIVAL KIT	(38.0)	(38.0)	(38.0)	(38.0)	(38.0)	(43.2)	(38.0)
CREW WEIGHT							
5 PERCENTILE, TOTAL	(185.2)	(180.2)	(187.2)	(180.2)	(188.2)	(179.2)	(187.2)
95 PERCENTILE, TOTAL	(279.0)	(274.0)	(281.0)	(274.0)	(282.0)	(273.0)	(281.0)
5 PERCENTILE PILOT	140.2	140.2	140.2	140.2	140.2	(140.2)	140.2
95 PERCENTILE PILOT	210.8	210.8	210.8	210.8	210.8	210.8	210.8
DROGUE	5.0	NONE	7.0	NONE	8.0	4.0	7.0
RECOVERY PARACHUTE	20.0	20.0	20.0	20.0	20.0	15.0	20.0
PERSONAL EQUIP, 5%	20.0	20.0	20.0	20.0	20.0	20.0	20.0
PERSONAL EQUIP, 95%	43.2	43.2	43.2	43.2	43.2	43.2	43.2
CANOPY/WINDSHIELD	–	–	–	–	(115.0)	–	–
TOTAL EJECTED WT, 5%	409.8	400.0	393.5	429.2	515.2	412.1	393.5
TOTAL EJECTED WT, 95%	503.6	493.8	487.3	523.0	609.0	505.9	487.3

1787-029W

complexity, size, cost, and risk. Each concept is represented by significant sizing and functional elements which are rated as low, moderate, high, or extreme with respect to their penalizing effect on MSLPC. A low score reflects a small penalty; a high score reflects a large penalty.

A separate performance ranking is shown on Table 3-9 with parameters rated excellent, good, fair, or poor with respect to their beneficial effect on MSLPC. A low score indicates a large performance benefit; a high score indicates a small performance benefit. Although free flight analyses of several escape concepts were subsequently conducted, the initial performance ranking reflected projected capabilities based on the established performance of extraction and ejection-type escape systems currently used or previously tested. As a result of this evaluation, the following MSLPC escape system concept conclusions can be made.

3.5.1 Conclusions

3.5.1.1 Deflection Wedge - Upright and Recline - These concepts are considered to have poor potential due to inherent complexity which would be compounded by

TABLE 3-8. ESCAPE CONCEPTS CONFIGURATION TRADEOFF
(Rating: 1 = Low; 2 = Moderate; 3 = High; 4 = Extreme)

	DEFLECTION WEDGE		TRACTOR ROCKET	SHIELD/ CANOPY	"B" SEAT VARIANT	CURVED TRACK	SUPINE CONCEPT
	UPRIGHT	RECLINE					
AIRCRAFT HARDWARE COMPLEXITY							
AIRCRAFT CANOPY	1	1	1	4	1	1	2
INSTRUMENT PANEL	2	2	2	3	2	1	2
BOOST/PREPOSITIONING	2	2	3	2	3	2	1
SEAT/ACFT INTERFACE STRUCTURE	1	1	3	4	2	1	1
CANOPY THRUSTERS	1	1	1	3	1	1	2
COCKPIT SIZE	3	3	3	3	3	3	1
WINDSHIELD JETTISON	1	1	1	4	1	1	3
INSTRUMENT PANEL JETTISON	1	1	1	4	1	1	3
TOTAL	12	12	15	27	14	11	15
ESCAPE-SYS HARDWARE COMPLEXITY							
BOOMS/WEDGE	4	4	–	–	3	–	–
PROTECTIVE BUCKET	1	1	1	4	2	1	2
DROGUE/STABILIZER	4	4	3	2	3	1	1
ROCKET/THRUST VECTORING	1	1	4	3	1	2	2
RESTRAINT	3	3	3	1	2	3	3
SEAT POSITIONING/SEPARATION	2	2	3	4	2	1	–
TRACKS	3	3	3	2	2	3	–
SEAT ASSEMBLY	4	4	1	3	3	2	1
TOTAL	22	22	18	19	18	13	9
SIZE/COST/RISK – PENALTIES							
WEIGHT	3	3	2	4	2	2	2
SIZE (COCKPIT VOLUME)	2	3	3	3	3	3	1
COST (LCC)	4	4	3	3	2	1	1
RELIABILITY RISK	2	2	1	3	2	1	2
MAINTAINABILITY RISK	2	2	1	3	2	1	1
DEVELOPMENT RISK	3	3	4	3	2	1	2
TOTAL	16	17	14	19	13	9	9
OVERALL TOTAL	50	51	47	65	42	33	33
1787-030W							

TABLE 3-9. ESCAPE CONCEPT PERFORMANCE TRADEOFF
(Rating: 1 = Excellent; 2 = Good; 3 = Fair; 4 = Poor)

ESCAPE SYS PERFORMANCE	DEFLECTION WEDGE		TRACTOR ROCKET	SHIELD/ CANOPY	"B" SEAT VARIANT	CURVED TRACK	SUPINE CONCEPT
	UPRIGHT	RECLINE					
SINK RATE	2	2	1	2	1	1	1
ROLL	1	1	4	1	2	1	1
ADVERSE ATTITUDE	3	3	3	4	2	1	1
SPIN	1	1	2	4	1	1	1
TAIL CLEARANCE	2	2	2	2	2	2	2
BODY ACCELERATIONS	2	2	4	2	2	2	2
COCKPIT CLEARANCE	2	2	2	3	3	3	1
TIMING (COCKPIT CLEARANCE)	2	2	1	1	3	1	1
STABILIZATION	4	3	2	2	1	1	1
HIGH SPEED	1	1	4	1	1	1	1
HIGH ALTITUDE	1	1	1	1	1	1	1
HIGH "G" ON AIRCRAFT	2	2	2	3	2	2	3
LOW ALT/ADVERSE ATT	2	2	2	4	3	2	1
TOTAL	25	24	30	30	24	19	17
1787-031W							

the solution to deployment and stability problems; therefore, no further effort is recommended.

3.5.1.2 Tractor Rocket - This concept is considered to have poor potential due to inadequate high speed/high G capability; therefore, no further effort is recommended.

3.5.1.3 Curved Track - Further development of limb restraint and containment is required for high G and crash conditions. This concept is considered to have good potential and further development is recommended.

3.5.1.4 Shield/Canopy - This concept offers fine air blast protection at the price of complexity. Performance is questionable in adverse attitude, roll, and spin conditions. The additional complication of extracting the crewman from the shield/canopy/seat in free flight makes a multi-mode system mandatory. This concept is considered to have poor potential.

3.5.1.5 "B" Seat Variant - In this concept, penalties are complexity (boom stabilizers) and a long time for aircraft separation; consequently, this concept is considered to have poor potential.

3.5.1.6 Supine Concept - This concept provides a clear upward (eyeballs-in) ejection path from within the smallest cockpit volume. Some of the inherent complexity will be necessary, in any case, to satisfy the normal MSLPC ingress/egress requirements and, therefore, should not be considered a severe penalty. However, further investigation is necessary to determine the impact of cockpit turbulence after the windshield and panel have been jettisoned. This concept is considered to have good potential.

IV. ESCAPE CONCEPT ANALYSIS

A series of multi-degree-of-freedom digital in-house computer programs have been developed to address the design and analysis of various vehicle escape systems. The basic trajectory program (A280 Ejection Seat Escape System) was used to assess the potential of MSLPC escape system concepts. This program simulates the motion of several bodies relative to each other and results in the establishment of a trajectory and corresponding time histories of the escape sequence from time of initiation to ground touchdown. The modular construction of A280 facilitated the inclusion of various subsystems into the main program. The systems modeled specifically for the MSLPC study were:

- Thrust Vector Control
- Vertical Steering Control
- Rocket Thrust Characteristics
- Drogue Parachute System
- Aerodynamic models for each concept.

The investigation of escape system concepts was conducted as a three-phase effort: 1) a maximum performance evaluation; 2) an intermediate performance evaluation; and, 3) a preliminary design of a preferred concept.

The initial maximum performance evaluation was complemented by an analysis of the aircraft separation and free flight of the Curved Track, "B"-Seat Variant, and Shield/Canopy concepts. In order to expedite this effort, it was necessary to make several assumptions with respect to the trajectory analysis:

- Simulations were restricted to the pitch plane
- Aircraft in 1.0 G level flight for most ejections
- Aerodynamic data were analytically derived
- Control laws were derived to simulate various rocket control systems
- Each trajectory was initiated at the seat launch position
- Velocities or pitch rates that result from a particular boost system were disregarded.

The second phase describes and documents the evaluation of intermediate performance capability concepts. Escape system concepts were defined and preferred concepts were selected for 450 KEAS and 600 KEAS performance envelopes. Tradeoff data were prepared for the 450 KEAS, 600 KEAS, and 687 KEAS concepts for the purpose of making a final selection for further development as a preliminary design.

The third phase involved the performance evaluation of the preferred 687 KEAS concept in conjunction with the preliminary design effort.

4.1 AERODYNAMIC DATA DETERMINATION

Because applicable wind tunnel data are generally nonexistent, an evaluation of the ejection performance of a variety of escape concepts with different aerodynamic shapes requires an analytical means of data definition. Specifically, the generation of pitch plane trajectories requires aerodynamic axial, normal, and pitching moment coefficient data for an angle of attack range from 0 to 360 degrees. A sufficiently general methodology that specifically addresses complex configurations over the speed range of this study (0 to 687 KEAS) was not available. However, Grumman's experience in high speed aerodynamics has resulted in the development of several computer codes that address the supersonic and hypersonic region. One of these, the High speed Aerodynamic Prediction Program (HAPP), appeared to be suitable for this study. The HAPP program provides all-axis supersonic (M 2.5) to hypersonic viscid/inviscid force and moment coefficients. Complex 3-D configurations are treated at all vehicle attitudes using the conventional yaw-pitch angular system. In addition, it supplies static and dynamic derivatives, loads and detailed surface pressures.

The HAPP computer code is structured around the mathematical formulation of the basic Newtonian numerical procedure. Accordingly, Newtonian estimates of pressure coefficient require only a knowledge of the local flow incidence relative to the vehicle surface, i.e.,

$$C_p = 2 \sin^2 \delta$$

where δ is the angle between the free stream velocity vector and the local body surface. The Newtonian Theory has been generalized to the empirical expression,

$$C_p = C_{Pref} \frac{\sin^2 \delta}{\sin^2 \delta_{ref}}$$

In this equation C_{Pref} is the exact pressure coefficient corresponding to δ_{ref}, a value of local body surface inclination selected as representative of the entire body. For a blunt body C_{Pref} becomes the stagnation pressure coefficient behind a normal shock. We now have,

$$C_p = C_{P_{stag}} \sin^2 \delta$$

where $C_{P_{stag}} = \frac{\gamma + 3}{\gamma + 1} \left\{ 1 - \frac{2}{(\gamma+3)M^2} \right\}$

where γ and M are the ratio of specific heats and mach number respectively. To cover a wide range of flight conditions, the Newtonian equation has been written as,

$$C_p = K \sin^2 \delta$$

where the factor K, is an empirical Mach dependent relation derived from data correlations of simple shapes over a wide Mach range. In this study, a Newtonian coefficient, K, value of 1.463 was used, which was obtained by substituting 1.5 for the Mach number in the expression for the stagnation pressure coefficient.

Before aerodynamic data were generated for the seat concepts, a validation effort was conducted to verify that the data generated by HAPP was appropriate to the speed range of this study. This was done by modeling a seat for the HAPP program for which data were already available. The resulting predictions from the HAPP program were then compared to the wind tunnel results at a representative Mach number.

The wind tunnel data used for this comparison were obtained from Ref. 10, and were based on a half-scale conventional escape seat. The Mach number chosen for the comparison was 1.5, which was the upper Mach limit of the wind tunnel data.

A comparison of the wind tunnel model and the corresponding modeling geometry used in the HAPP program is shown in Figure 4-1, a data comparison is shown in Figure 4-2 and tables in Appendix B. Surprisingly good correspondence was obtained for the coefficient data with both peak values and crossover points agreeing very closely. No additional effort was expended beyond this point to improve the data correlation by a more detailed modeling of the seat geometry or variations in the aerodynamic pressure laws.

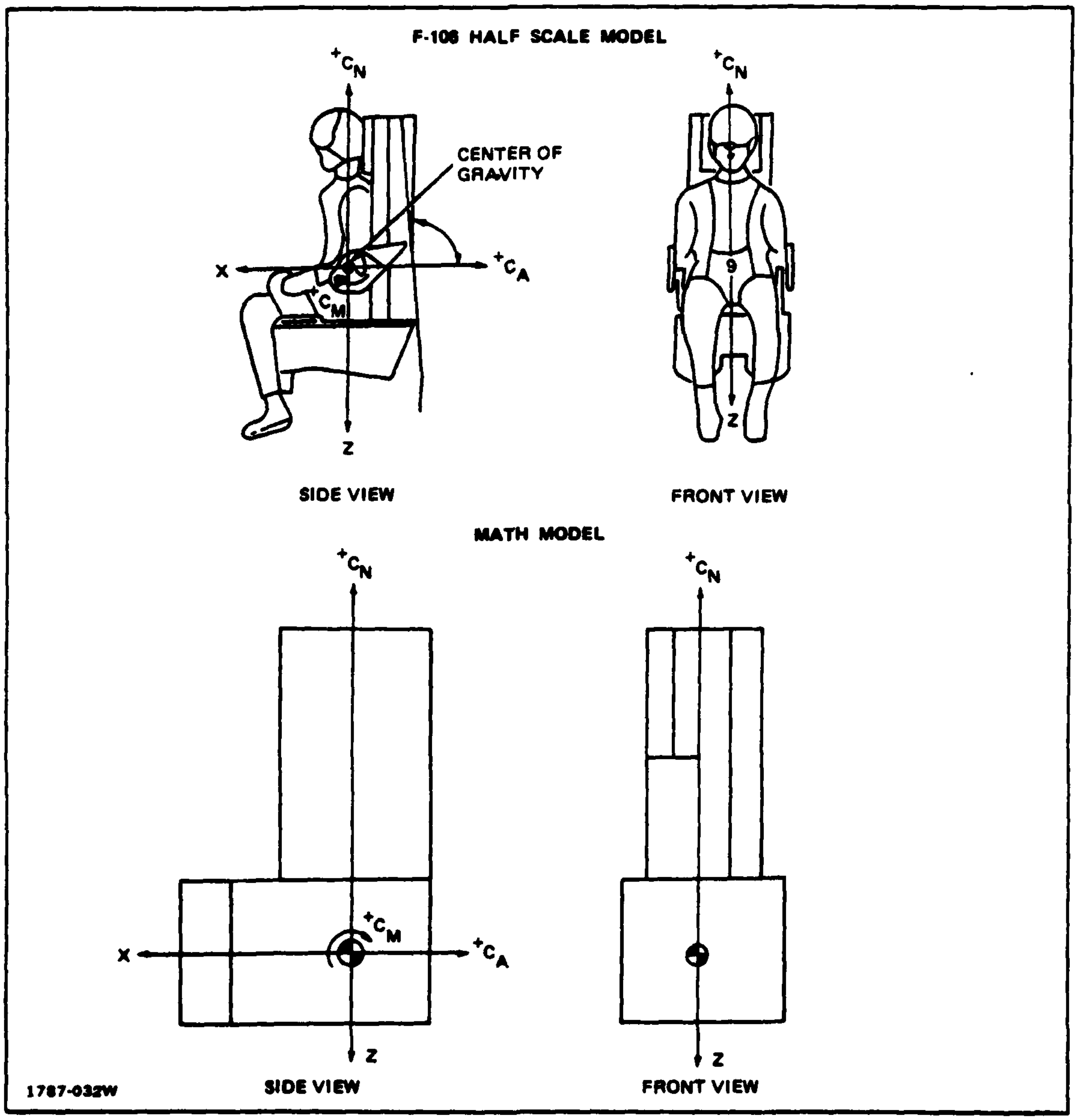


Figure 4-1. Aerodynamic Model

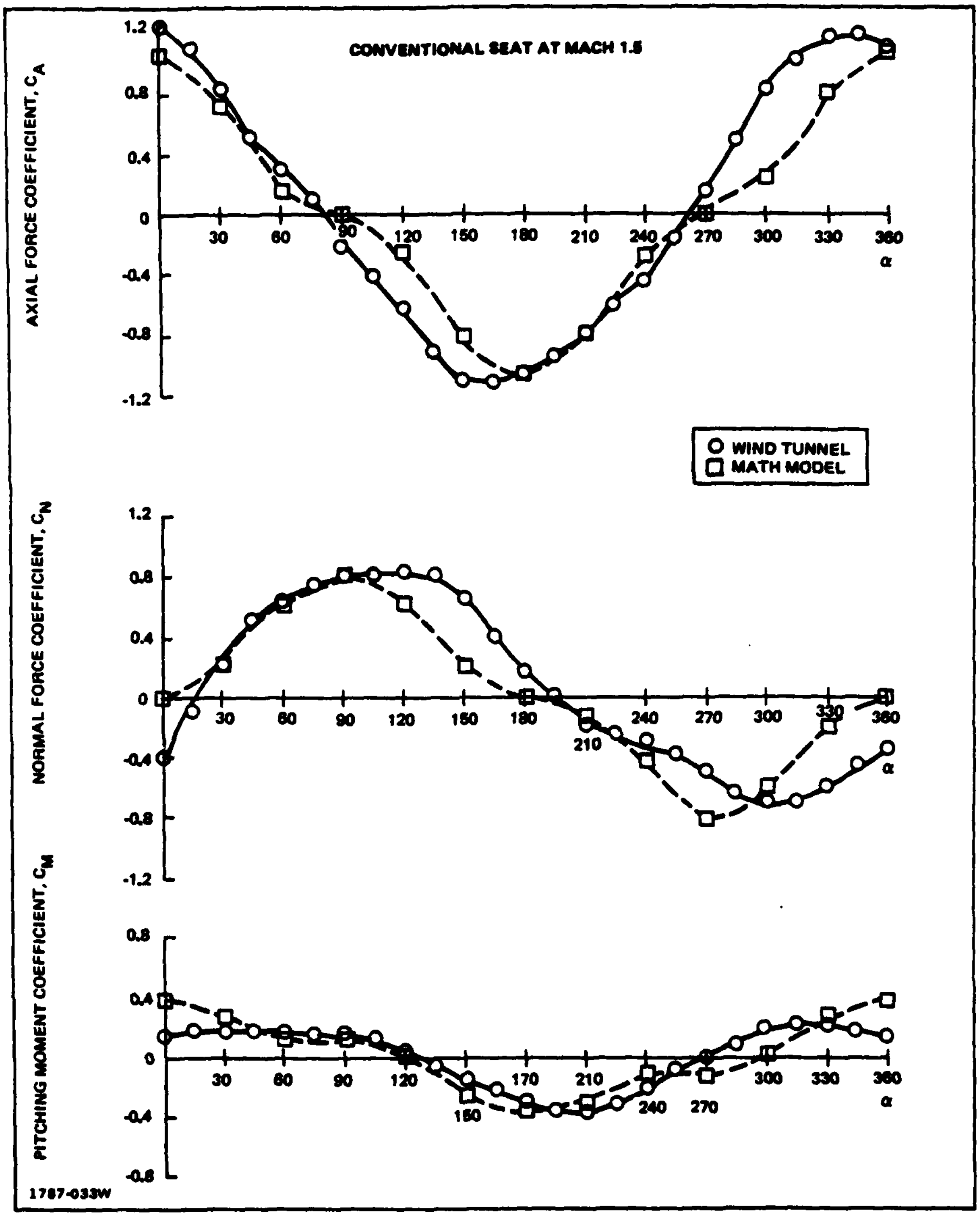


Figure 4-2. Correlation of Math Model with Wind Tunnel Results

On the basis of this comparison, data was derived for the curved track concept, the "B" seat variant concept and the shield/canopy concept. Each concept was provided with a modeling geometry (Figure 4-3) for the HAPP program. The aerodynamic data for all seats was generated at only one Mach number (1.5) and used throughout the Mach number range in this study. The variations in the data due to Mach number were not expected to alter the results of the study significantly.

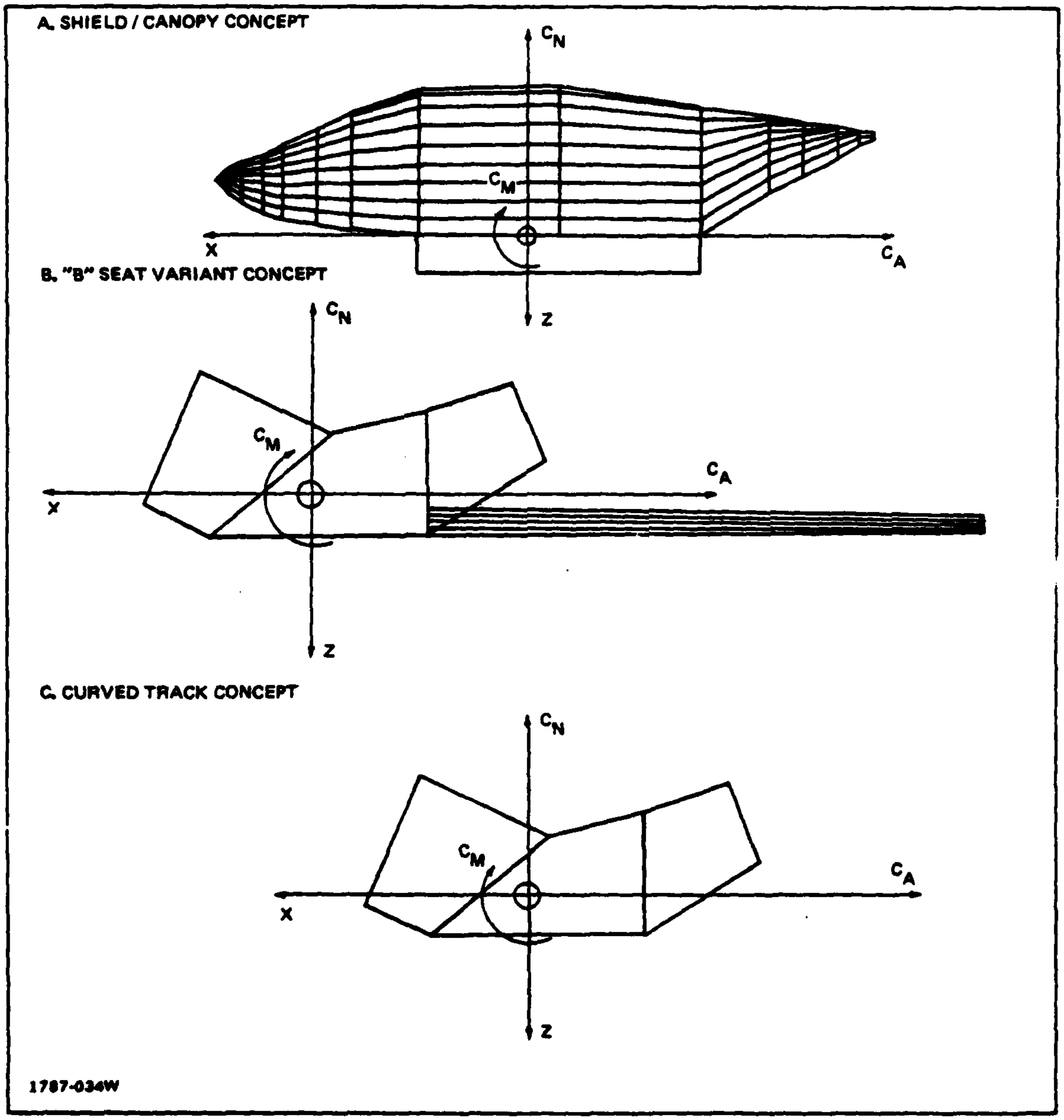


Figure 4-3. Concept Geometry, Aerodynamic Model, Side View

4.2 ROCKET CONTROL SYSTEMS

4.2.1 Thrust Vector Control

An idealized Thrust Vector Control (TVC) system was devised as an on-line control for those escape concepts lacking sufficient aerodynamic stability with a fixed seat rocket. TVC was applied in the high dynamic pressure region ($q = 1600$ psf) of the escape envelope, because of the larger destabilizing aerodynamic forces and moments acting on the seat/man mass. In addition, the need for protection from wind blast and prevention of limb flailing dictated attitude positioning of the seat/man along the ejection trajectory prior to drogue deployment. Wind blast protection was provided by positioning the seat bottom facing into the air stream along its flight trajectory. This was accomplished through the control system sensing the aircraft/seat attitude at ejection and biasing the attitude by a prescribed amount from the initial launch position.

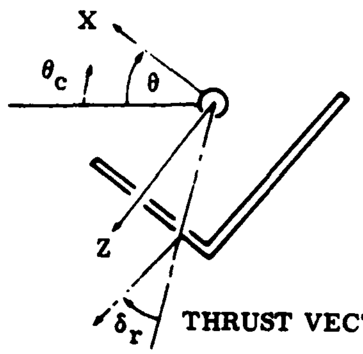
A control model was selected for the high speed flight regime consisting of a single axis attitude control in pitch with an attitude bias to orient the seat/man relative to the air stream, represented by the aircraft's velocity vector. The model was patterned after the system described in Reference 3 with a gimballed rocket motor to change thrust orientation. Thrust movement was restricted to a maximum deflection in the seat pitch plane of ± 20° and a maximum deflection rate of ± 700°/sec. Seat attitude and attitude rate information at initiation of ejection and during the seat/man flight was presumed to be available from sensors located on the seat.

The feedback control law evolved from Reference 3 consists of attitude feedback for pitch positioning and rate damping to provide seat stability.

CONTROL LAW

$$\delta_R = \int_0^t \left[\frac{1}{T} (K\theta - \delta_R) + K_A (\theta - \theta_c) \right] dt$$

SEAT DIAGRAM



NOMENCLATURE

δ_R = Thrust deflection angle;

T = Control system time constant;

K, K_A = Control system gains;

θ = Seat pitch attitude;

θ_c = Seat pitch command attitude;

t = Time.

No attempt was made to optimize gains or time constants, since the control law elements correspond only conceptually to physical components. Values of these parameters were chosen to provide a dynamic system response representative of the systems described in Reference 3.

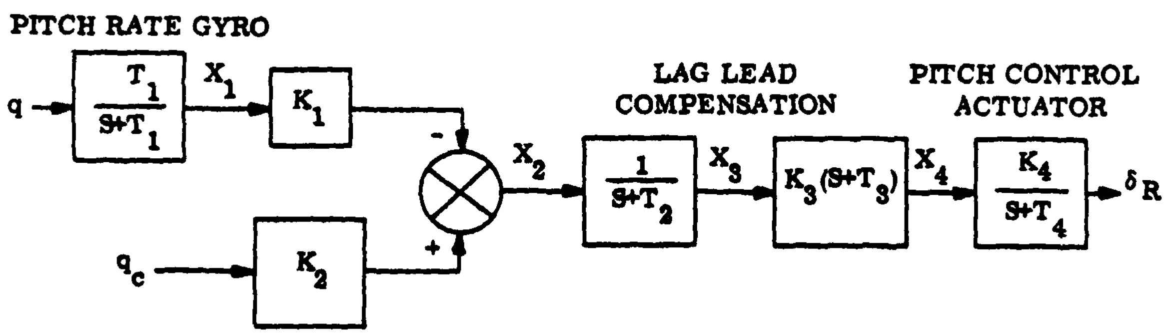
The TVC system provides wind blast protection by maintaining the attitude existing at system initiation. Protection is required at speeds above 600 KEAS, which is a nominal value based on the upper limit of conventional systems. At low speed and low altitude, when the aircraft is in a steep dive or roll condition, this attitude positioning generally provides improved escape capability over a conventional fixed seat rocket. However, at bank and dive angles beyond 90°, an improvement in escape capability is desirable, particularly if rocket thrust times of 0.5 seconds or greater are used. To address this escape region, a Vertical Steering Control (VSC) was utilized.

4.2.2 Vertical Steering Control

The purpose of a Vertical Steering Control (VSC) system is to select a vertical-up ejection trajectory for an escape seat, irrespective of aircraft attitude at initiation of ejection. The primary benefit of this concept over the TVC system derives from ejections at low altitude with the aircraft in an inverted or near inverted attitude.

The Naval Weapons Center (NWC) China Lake, California, has implemented a preliminary version of a VSC design and successfully demonstrated the feasibility of the concept. Static tests have been conducted which demonstrated controlled vertical seeking maneuvers from a platform-mounted cockpit structure suspended from a tower. The design consists essentially of a three-axis strap-down rate gyro sensor system, micro computer, gimballed rocket motor, hydraulic actuators, servo valves, and hydraulic and electrical power supplies (Reference 8). The current design required initialization with respect to aircraft attitude. The NWC provided a description of this system, including vertical steering logic, control equations, and system parameters which were the basis of the model used in this study. A schematic representation of the pitch channel part of the control system showing its main components and the corresponding control equations, follows:

VERTICAL STEERING CONTROL SCHEMATIC PITCH CHANNEL



Control Equations

$X_1 = T_1 (q - X_1)$

$X_2 = -K_1 X_1 + K_2 q_c$

$X_3 = X_2 - T_2 X_3$

$X_4 = K_3 (X_3 + T_3 X_3)$

$\delta_R = K_4 X_4 - T_4 \delta_R$

Control Parameters & Variables

X_1, X_2, X_3, X_4 = State variables

T_1, T_2, T_3, T_4 = Time constants

K_1, K_2, K_3, K_4 = Gains

q, q_c = Seat body axis pitch rate and pitch rate command, respectively

δ_R = Seat rocket thrust deflection angle

S = Laplace operator

The features of the model are conceptual and represent a preliminary design. The model is sufficiently representative, however, of a realistic configuration useful to this study, notwithstanding an identical existing but unused seat roll control arrangement. Since the first phase of the study was restricted to the pitch plane, the vertical steering control logic was restricted to the pitch channel to effect recoveries from an inverted attitude by means of pitch control commands. The second and third phases, however, effect recoveries from an inverted attitude by commanding seat roll and pitch responses.

VSC can be considered as an alternative to TVC at speeds below 600 KEAS. A blended system combining the attributes of TVC and VSC is proposed, rather than two separate systems. Thrust vector deflection angles, rates, and thrust time history data were the same for both the VSC and TVC systems.

4.3 PERFORMANCE PROFILE

The primary emphasis during the first phase was directed toward the high speed, high dynamic pressure environment where the escape problems were considered to be more critical, while the design difficulties were relatively unexplored. Each concept was investigated to identify such specific problems as:

- Collisions with parent aircraft
- Stability affecting normal seat operation

- Excessive G forces on crewman
- Inadequate protection from wind blast
- Minimum terrain clearance.

Problems involved in low speed ejections essentially concern the difficulty of escape from an aircraft at low altitude in high sink rate adverse attitude conditions. These problems are addressed in the investigation of a Vertical Steering Control system which redirects the ejection trajectory.

4.4 PERFORMANCE EVALUATION

4.4.1 Curved Track Concept

To survive windblast in a high dynamic pressure, "q" environment it is mandatory that the seat maintains a near positive flight attitude until a tolerable wind force level has been reached through deceleration. The aerodynamic stability of the basic seat does not alleviate the condition in that the stable trim point is approximately -20°. The pitching moment coefficient transferred to the seat CG as a function of the angle of attack is shown in Figure 4-4.

It was necessary, therefore, to actively stabilize the seat in a positive attitude or at worst a zero attitude throughout the flight.

This requirement resulted in the rejection of a fixed rocket with its thrust vector oriented through the seat center of gravity, since it was not capable of providing the necessary attitude control. A rocket containing thrust vector control was selected to fulfill the requirements of controlling the attitude of the seat, as well as producing sufficient thrust to clear the aircraft structure. For the initial analysis, a rocket with a 5000-pound thrust level and a 0.5-second duration was utilized. The rocket thrust line was oriented 30° forward of vertical in anticipation of a position flight attitude of 30° which would then direct the thrust vector in a near vertical direction. Two trajectories were calculated to determine the rocket control capability to control the seat at different command attitudes (Figure 4-5). This illustration shows the trajectories of the seat relative to the aircraft for ejections at Mach 2.4, an altitude of 40,000 feet, and a dynamic pressure ("q") of 1600 psf.

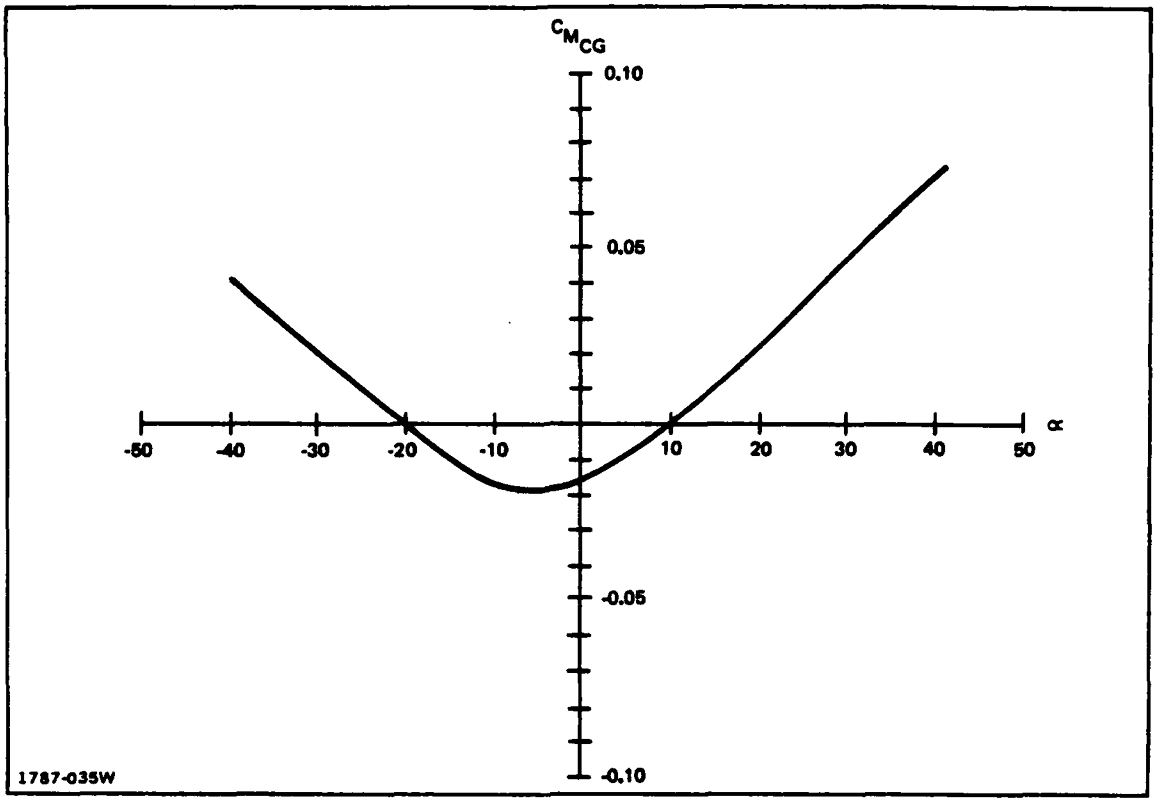


Figure 4-4. Curved Track Pitching Moment vs Angle of Attack

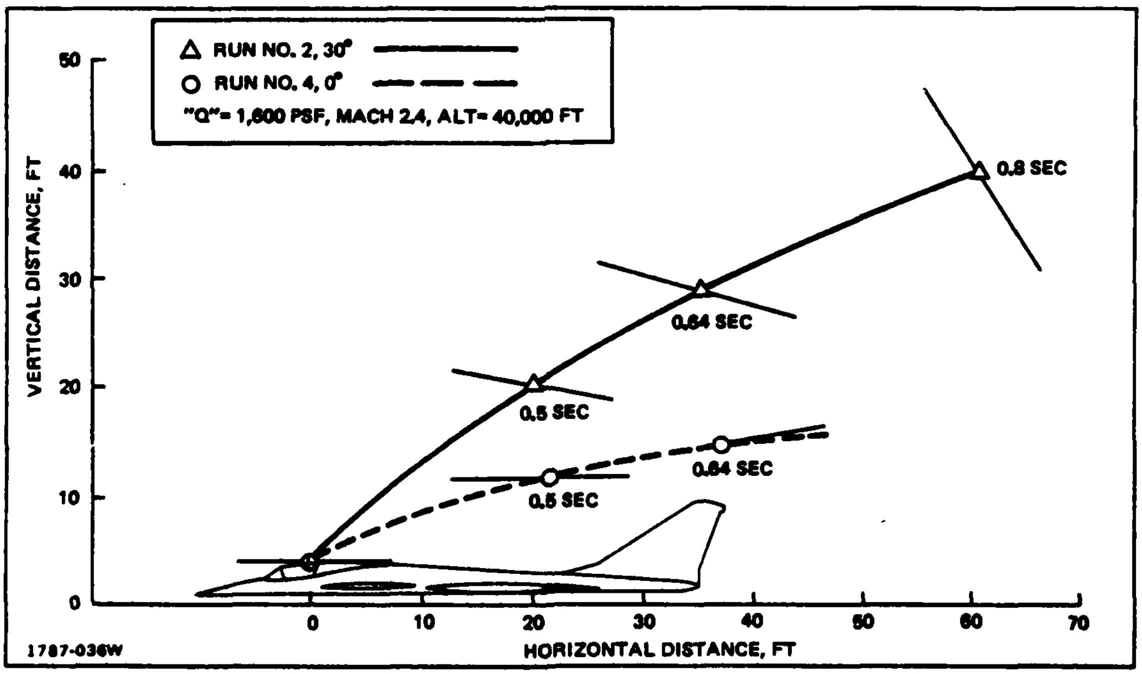


Figure 4-5. Curved Track Trajectories/Effect of Command Attitude

The trajectories are initialized at the launch position (time = 0) at which time the rocket begins thrusting. The initial attitude of the seat at time = 0 is zero degrees relative to the aircraft. For the first ejection, the rocket control system command attitude attempted to maintain the zero degree attitude, and in the second ejection a 30° positive command attitude. Both trajectories adequately clear the aircraft tail, however, the 30° command attitude ejection pitched up uncontrollably such that neither the rocket control system nor a 4-foot-diameter drogue chute could check the seat motion. The control system was capable of controlling the zero attitude with a slight negative drift. Figure 4-6 shows the pertinent time histories associated with the two trajectories. The time histories of the spinal G indicate that with the rocket thrust 30° forward of vertical the forward thrust component is instrumental in reducing the spinal G loads. At rocket burnout, approximately 0.5 seconds, the spinal G increase to sustained levels above 10 G due to aerodynamic drag.

The G convention (Figure 4-7) used throughout the study is an integral part of the basic computer simulation methodology adopted initially to expedite the calculation of aerodynamic coefficients for the various escape concept configurations. Because the computer program was devised for an upright ejection seat system, the axial pitch plane references appear displaced 90° when applied to the MSLPC concepts. Time constraints precluded revision to conform to conventional relationships.

Figure 4-8 presents the time histories of two ejections at Mach 1.2, an altitude of 7500 feet and a "q" of 1600 psf. The rocket thrust for the 0.5-second duration rocket was repeated and compared with a 2.0-second duration thrust curve for its effect on spinal G. As anticipated, the forward thrust component was instrumental in reducing the spinal G to relatively low levels throughout the rocket burn. The increase of spinal G at rocket burnout is induced by the aerodynamic drag produced by the seat and inflation of the stabilization drogue chute. It was necessary to reduce the deceleration of the seat drogue system such that the spinal G remain at the low levels experienced during rocket burn. This was accomplished by varying the drogue canopy sizes to determine the maximum drogue canopy required to provide seat pitch stabilization. Figure 4-9 presents the results of three ejections using a 4-foot, 3-foot, and 2-foot hemisflow ribbon canopy. The 2-foot canopy drogue provides adequate pitch stabilization with minimum deceleration. This size was

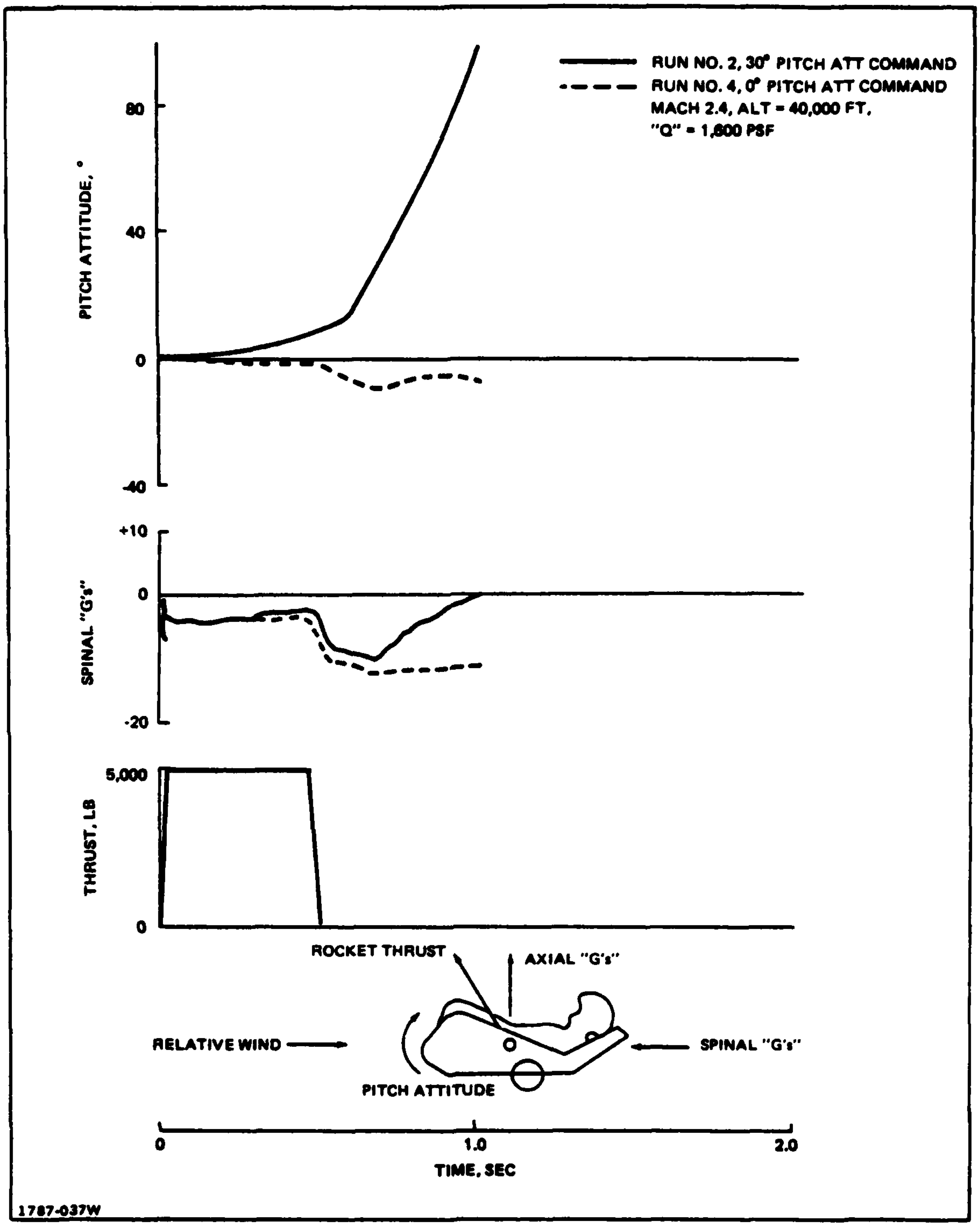
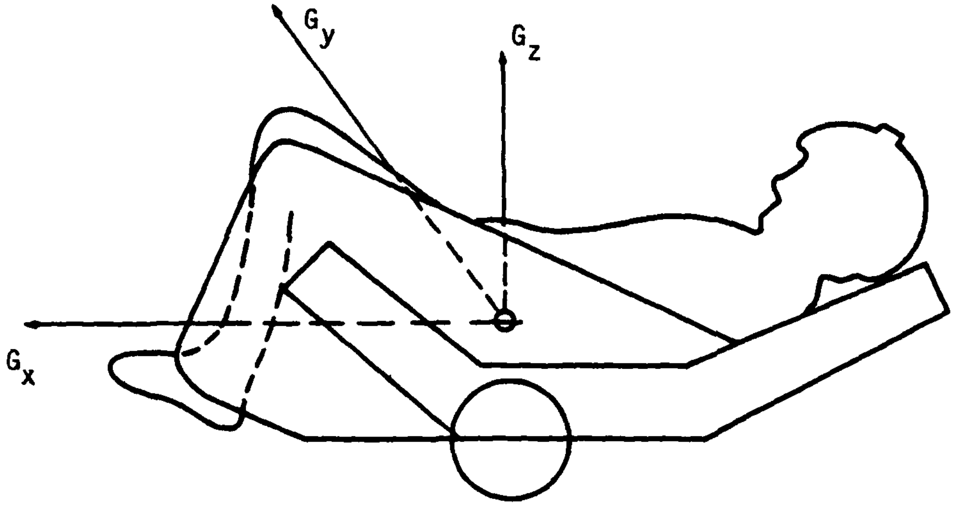


Figure 4-6. Curved Track Time Histories/Effect of Command Attitude



WHERE:

$G_x = \frac{a_x}{32.2}$ — $+G_x$ is eyeballs - up; $-G_x$ is eyeballs - down } SPINAL "G's"

$G_z = \frac{a_z}{32.2}$ — $+G_z$ is eyeballs - in; $-G_z$ is eyeballs - out } AXIAL "G's"

$G_y = \frac{a_y}{32.2}$ — $+G_y$ is eyeballs right; $-G_y$ is eyeballs left } LATERAL "G's"

1787-038W

Figure 4-7. "G" Convention

selected and utilized on all seat concepts for all succeeding ejections. A hemisflow ribbon drogue was selected as the decelerator because of its superior stability and inflation characteristics at supersonic speeds.

Final considerations were given to the design of the proper thrust time history and its effect on aircraft tail clearance. Four ejections were run for this purpose and the resulting trajectories are present in Figure 4-10. The thrust time histories used for this study are representative and consistent with the capability of existing rocket technology development. It is obvious that tail clearance is determined by the thrust developed during the first 0.5 second of the ejection sequence. The curve corresponding to Run 18 provided adequate tail clearance and was selected as the final rocket thrust schedule to be utilized for this system.

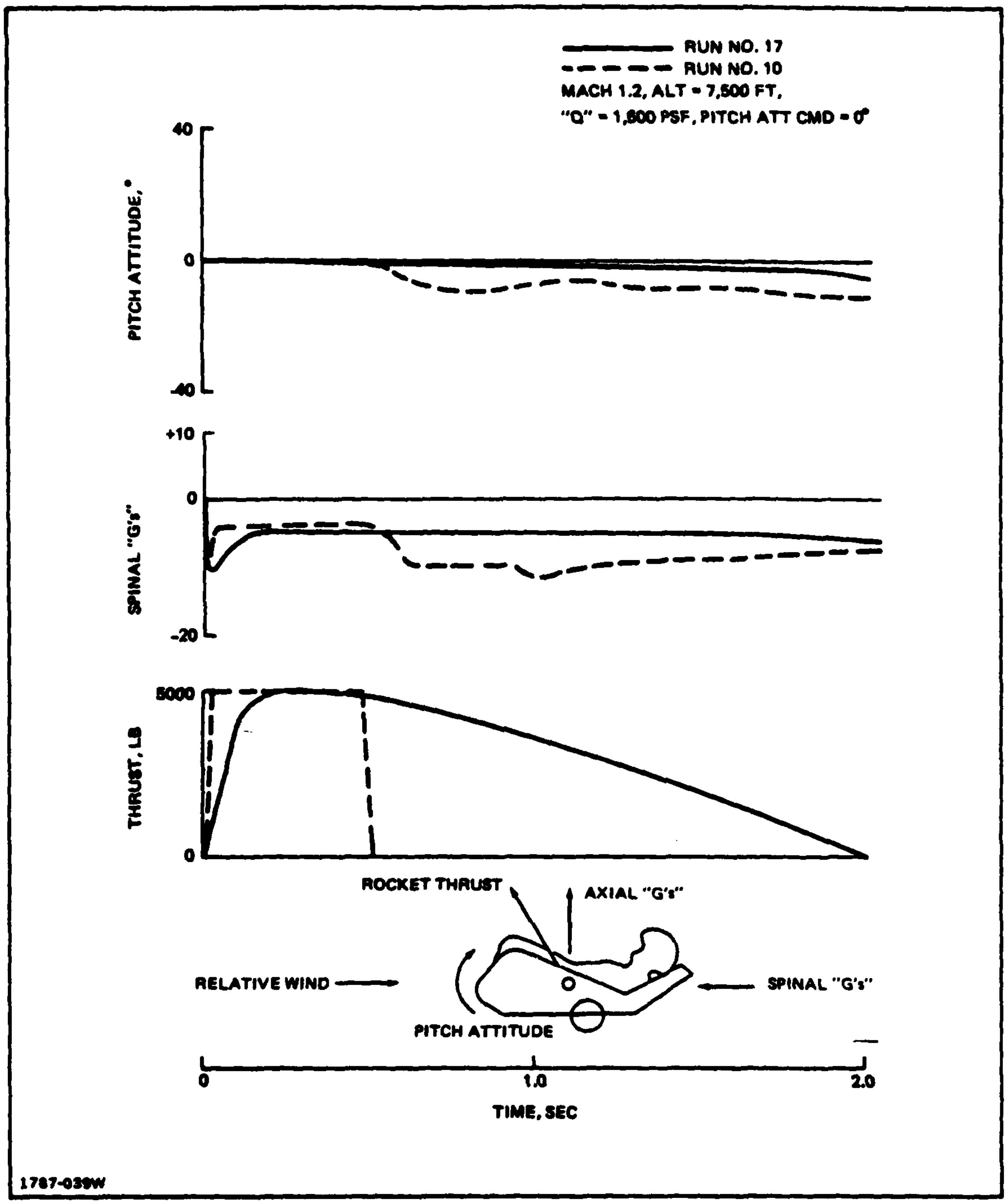


Figure 4-8. Curved Track Time Histories/Effect of Thrust Duration

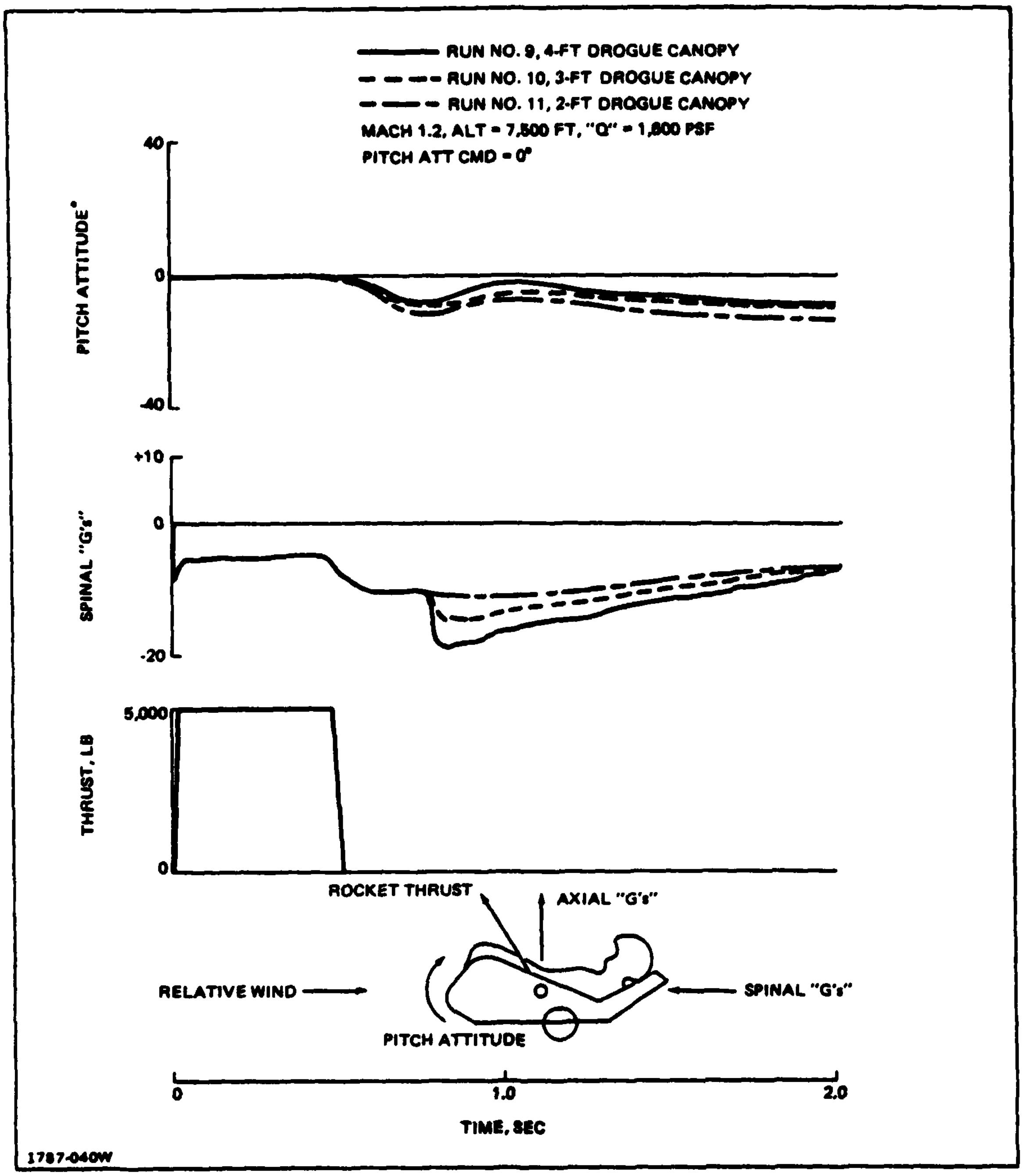


Figure 4-9. Curved Track Time Histories/Effect of Drogue Canopy Size

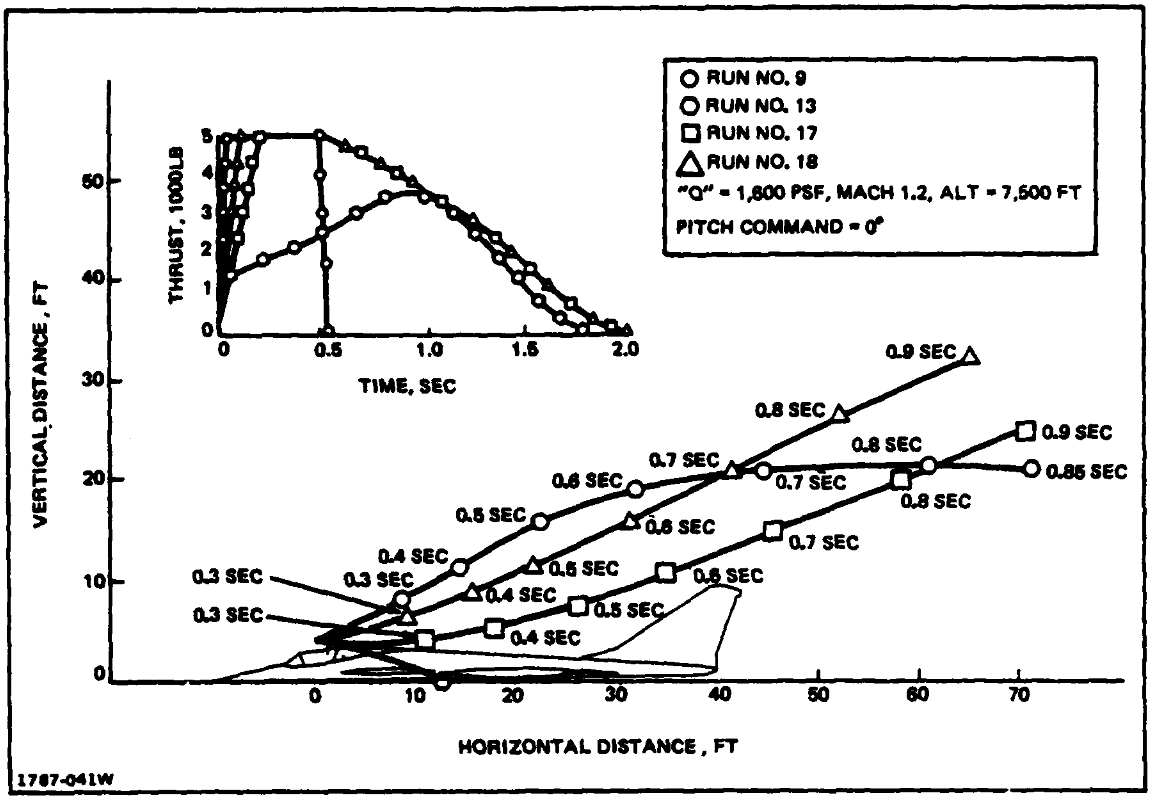


Figure 4-10. Curved Track Trajectories/Effect of Rocket Thrust

The final configuration achieved as a result of this study consists of the following:

- Zero-degree exit attitude
- TVC Rocket
- High impulse thrust level
- Two-Second duration rocket burn
- Rocket orientation 30° forward of vertical
- Zero-degree attitude command
- Two-foot hemisflow drogue chute.

A thrust orientation of approximately 30° forward of seat vertical was found to be a convenient way of relieving spinal accelerations. A more vertical orientation can be traded off against improved tail clearance and reduced seat rocket thrust levels at high speeds or for improved trajectory height in low altitude dives.

The escape system performance for this configuration was evaluated by calculating trajectories at selected flight conditions throughout the envelope. The effects of dynamic pressure are illustrated in Figure 4-11, where trajectories are presented for dynamic pressures of 1600 psf, 1200 psf, and 790 psf at a Mach number of 1.6. Figure 4-12 shows the corresponding time histories for each trajectory. The performance of the curved track concept is satisfactory for these flight conditions, in that it meets the following criteria:

- No collision with parent aircraft
- No stability problems affecting normal seat operation
- Minimal G forces on crewman
- Adequate protection from high "q" windblast.

4.4.2 "B" Seat Variant

The "B" Seat Variant concept relies primarily on extendible booms for passive flight stabilization. This eliminated the need for active stabilization

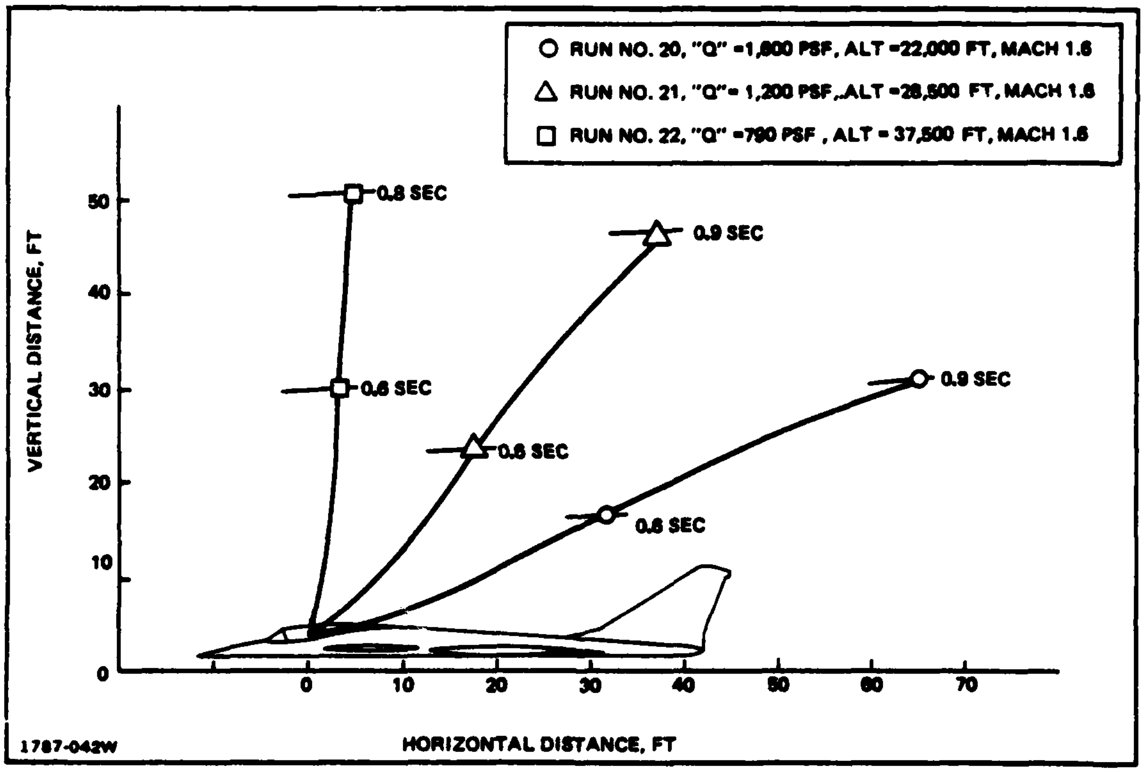


Figure 4-11. Curved Track Trajectories/Dynamic Pressure Variation

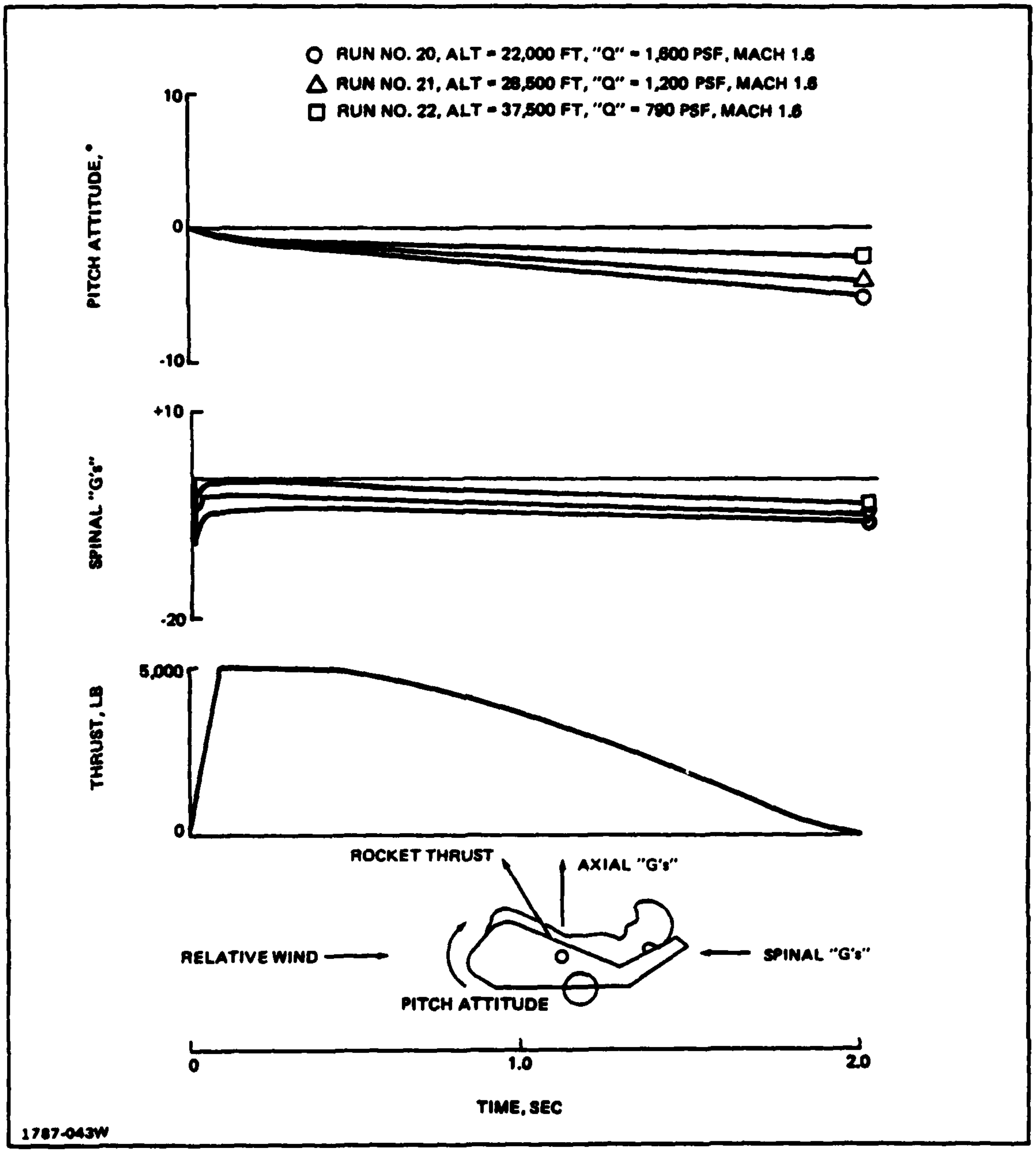


Figure 4-12. Curved Track Time Histories/Dynamic Pressure Variation

such as the thrust vector control system. The "B" seat variant concept does require a seat rocket to assure adequate clearance of aircraft structure throughout the flight envelope. A fixed rocket was configured for the "B" seat which utilized a 0.5-second duration burn time and a 5000-pound thrust level. The rocket was oriented 30° forward of vertical for the alleviation of spinal G. To protect the crewman from the effects of wind blast, an attempt was made to stabilize this seat in a positive flight attitude. In addition, the positive attitude was expected to reduce spinal G loads on the crewman by redistributing the deceleration forces following rocket burnout. The first trajectory calculation was initiated with the "B" seat positioned in a 30° positive attitude relative to the aircraft. The aircraft was at Mach 1.2, an altitude of 7500 feet and a "q" of 1600 psf at the time of ejection. Figures 4-13 and 4-14 present the trajectory and time histories for this run.

The trajectory shows adequate tail clearance; however, the seat pitches down violently and eventually stabilizes at approximately -10°. At rocket burnout (approximately 0.5 second) the seat is at a zero pitch attitude which results in a relatively high sustained spinal G loading. Since the fixed rocket does not utilize an active control system, the aerodynamic trim point becomes extremely important in determining the flight characteristics of the "B" seat variant. The

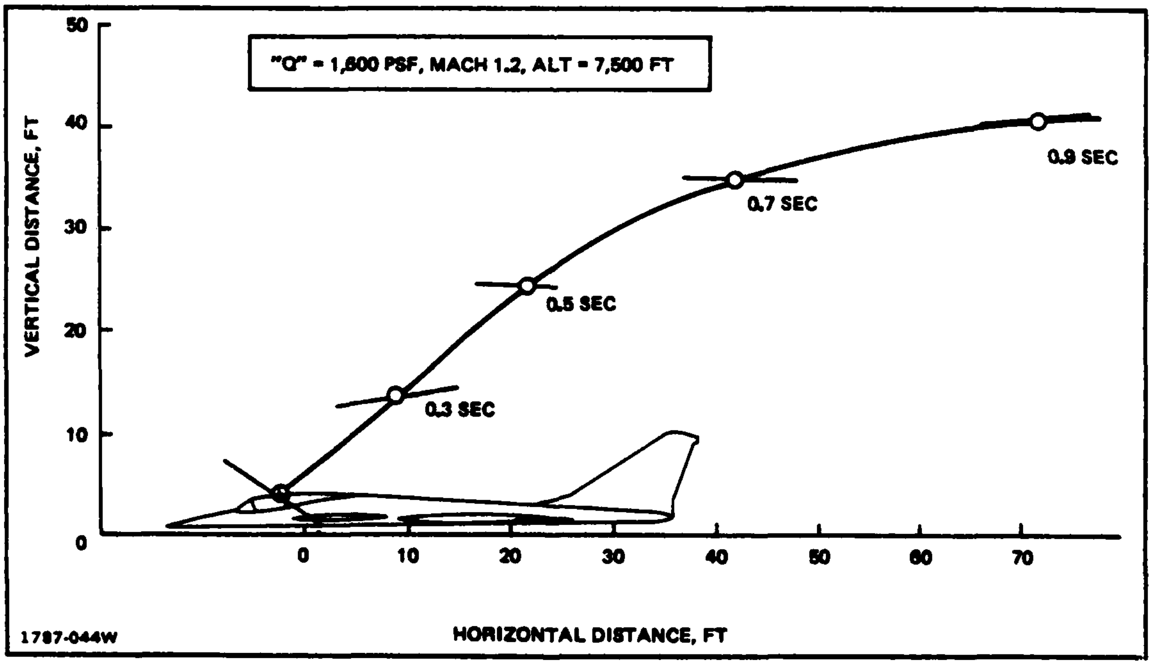


Figure 4-13. "B" Seat Variant Trajectory/30° Exit Attitude

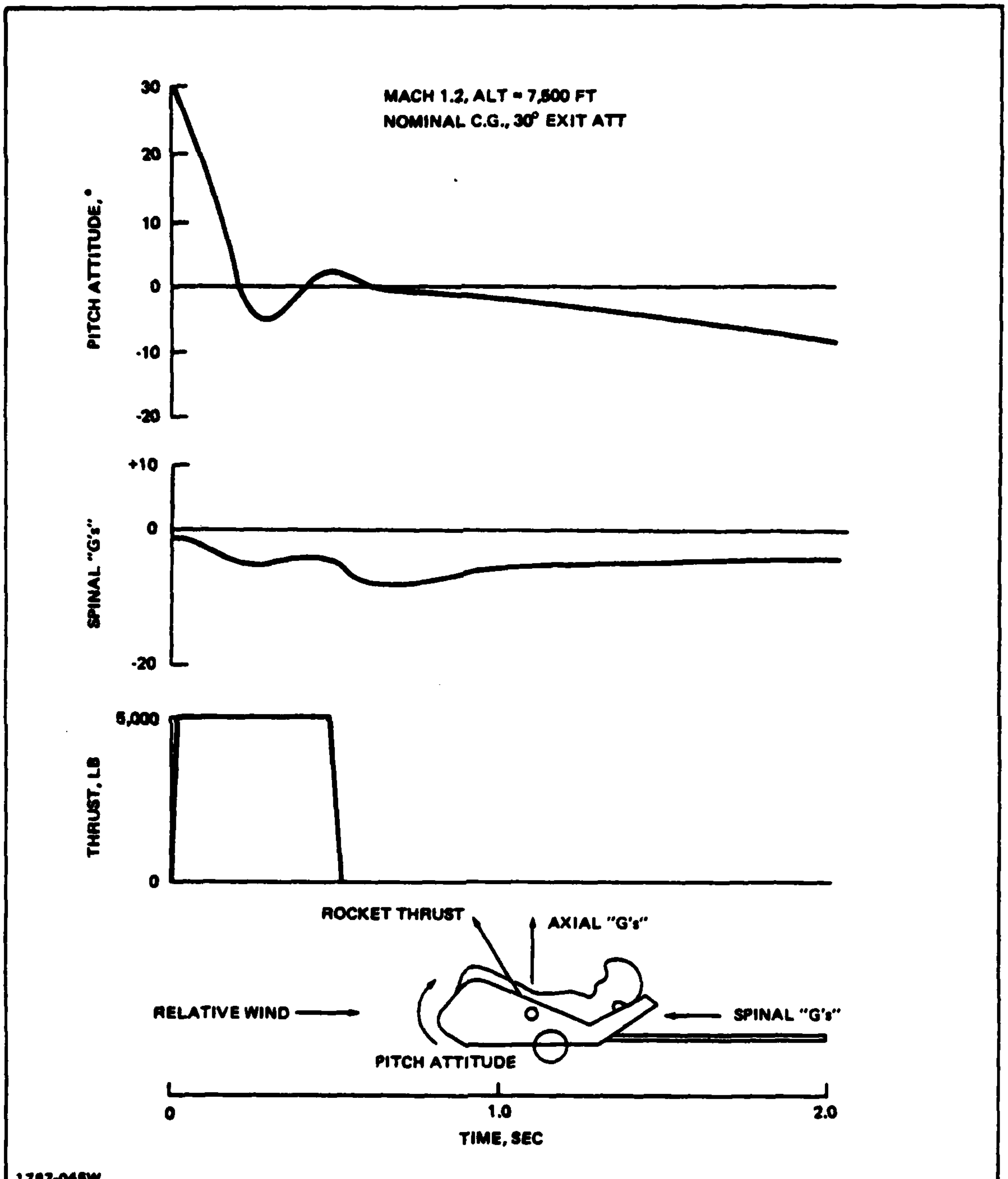


Figure 4-14. "B" Seat Variant Time Histories/30° Exit Attitude

pitching moment coefficient about the seat CG, as a function of the angle of attack, is shown in Figure 4-15.

Two curves are presented, representing the pitching moment corresponding to the original CG location (labeled nominal CG), and one corresponding to a CG located at the seat reference point. The difference in CG location resulted in a shift in the stable trim point from -10° to +10°. Trajectories were calculated for the new CG location at two exit attitudes 0° and +18°. The flight conditions for these ejections were Mach 1.2, altitude 7500 feet, and a "q" of 1600 psf. The resulting time histories are presented in Figure 4-16. Both trajectories trimmed out quickly and continued to fly at approximately +10°. The exit attitude had a negligible effect on the alternate trajectory and in both cases the spinal G were within tolerance limits.

The configuration resulting from this analysis consists of the following:

- 18° exit attitude (not essential for final configuration)
- Fixed rocket
- 0.5-second duration thrust
- 5000-pound thrust level
- Rocket oriented 30° forward of vertical
- CG at seat reference point.

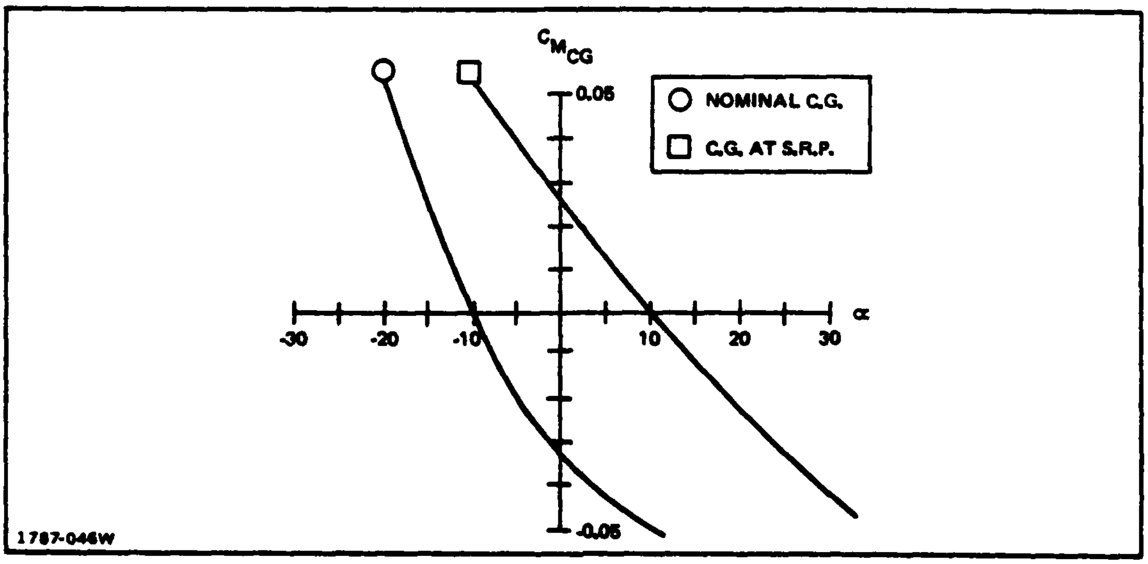


Figure 4-15. "B" Seat Variant/Pitching Moment vs Angle of Attack

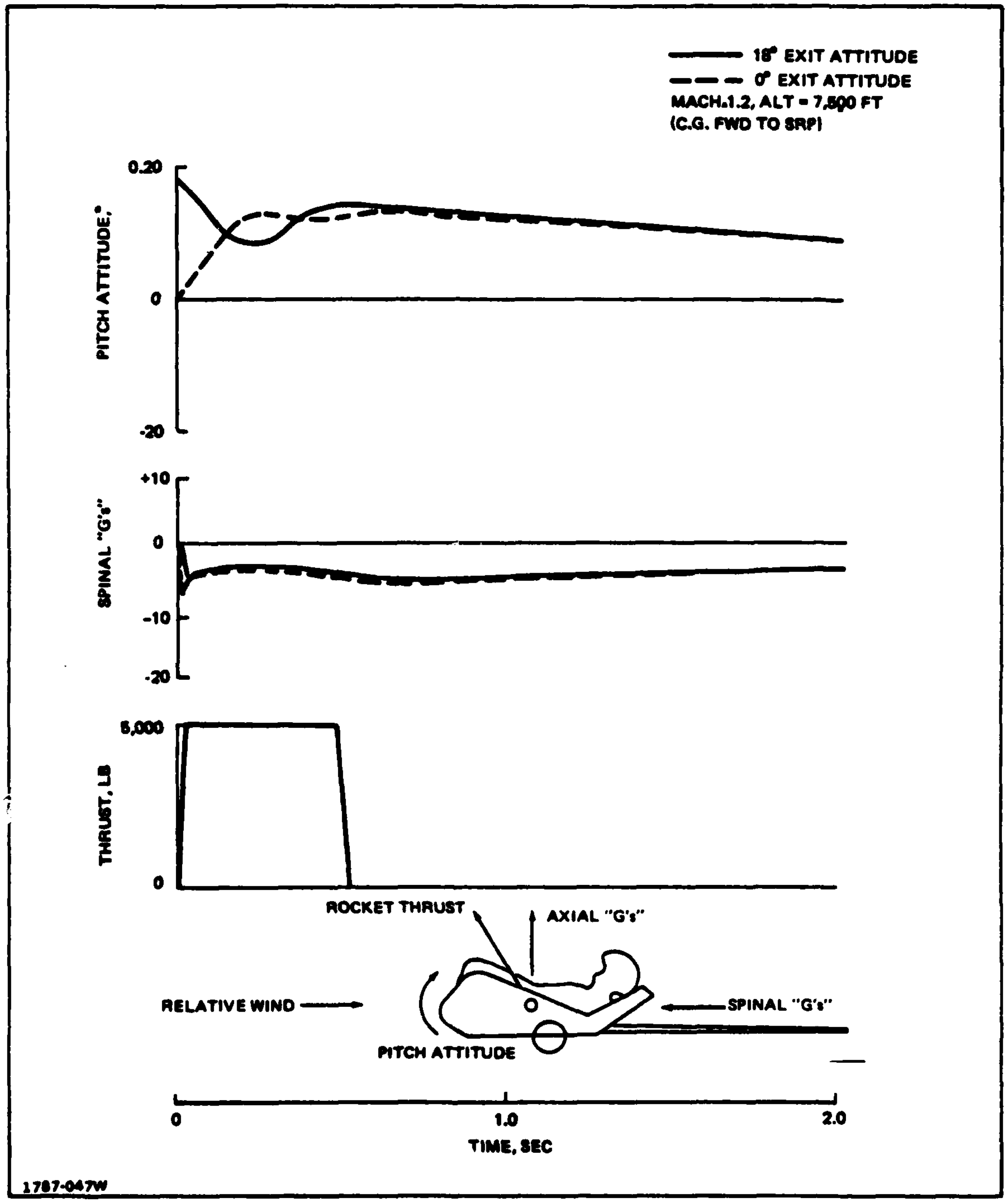


Figure 4-18. "B" Seat Variant Time Histories/Exit Attitude

It should be noted that the 18° exit attitude was retained but is not essential for the final configuration.

The escape system performance for this configuration was evaluated by calculating trajectories at selected flight conditions throughout the flight envelope. The effects of dynamic pressure are presented in Figure 4-17, where trajectory plots are shown for dynamic pressures of 1600 psf, 1200 psf, and 700 psf at a Mach number of 1.6. Figure 4-18 shows the corresponding time histories for each trajectory. The performance of the "B" seat variant concept is satisfactory for these flight conditions with respect to the following criteria:

- No collisions with parent aircraft.
- No stability problem affecting normal seat operation
- No excessive G forces on crewmen
- Adequate protection from high G windlbast forces.

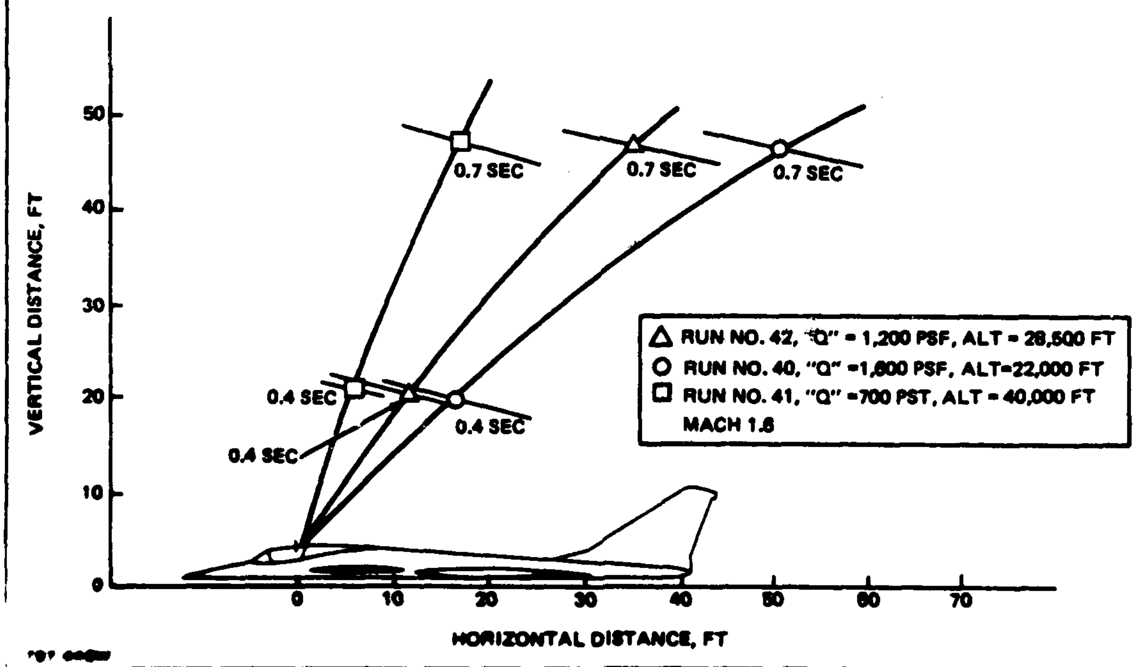


Figure 4-17. "B" Seat Variant Trajectories/Dynamic Pressure Variation

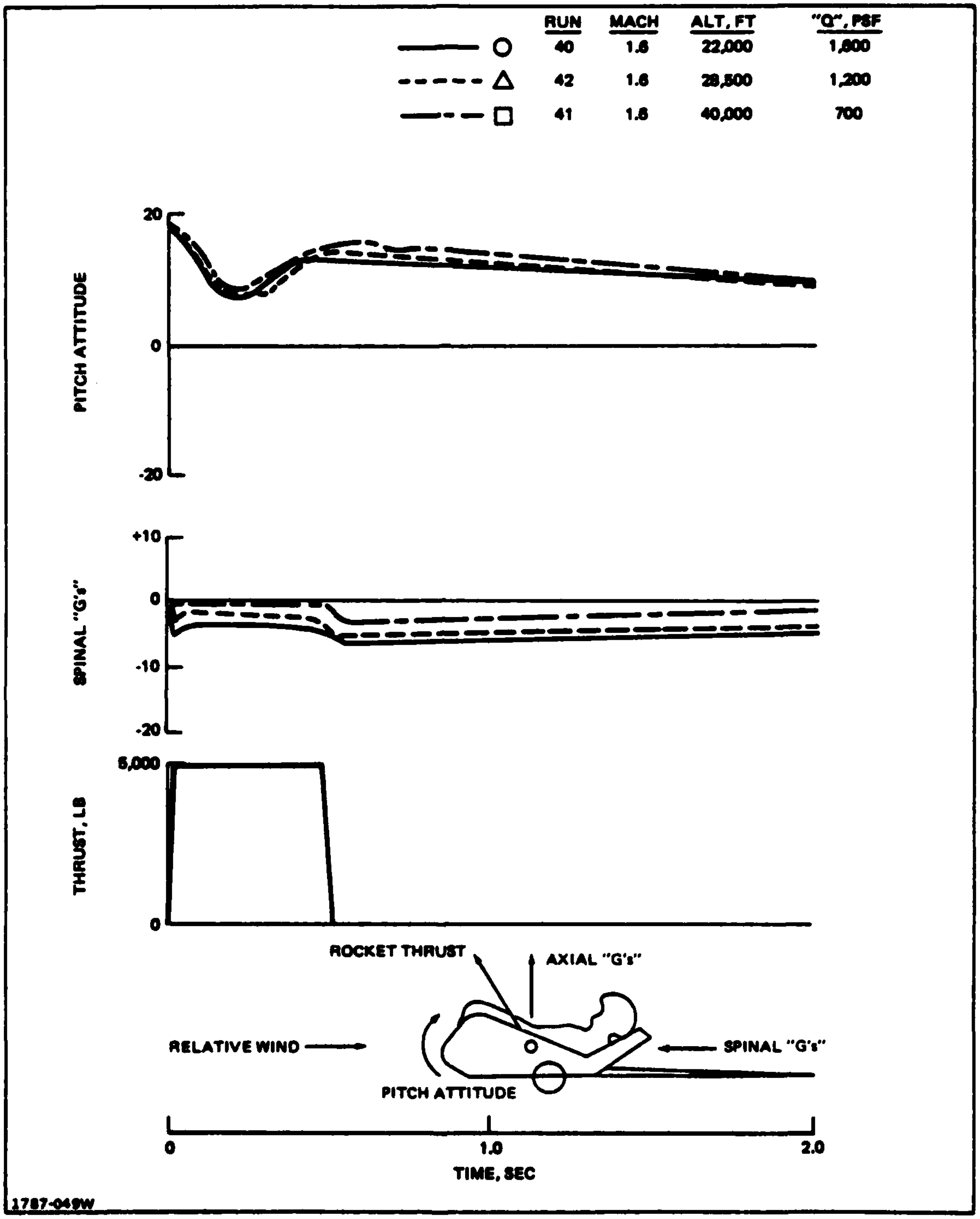


Figure 4-18. "B" Seat Variant Time Histories/Dynamic Pressure Variation

4.4.3 Shield/Canopy Concept

The performance characteristics acquired from the investigation of the curved track concept was used for the analysis of the shield/canopy concept. Since the shield/canopy configuration is an aerodynamically unstable body, a thrust vector control rocket was incorporated into the design of this configuration. The rocket characteristics consisted of a 2-second burn duration, high impulse thrust time history, and a rocket thrust line oriented 30° forward of vertical. A calculation was made for a shield/canopy ejection at Mach 1.2, an altitude of 7500 feet, and a "q" of 1600 psf. The attitude at launch (time = 0) was zero degrees, and the thrust vector control attitude command was set to maintain this zero attitude throughout the rocket burn. Figures 4-19 and 4-20 present the trajectory and time history data for this simulation. The aerodynamic loading on the shield/canopy, as it entered the airstream, resulted in a large negative pitching moment. As the canopy pitched down, negative lift developed, counteracting the upward thrust of the rocket. As a result the canopy did not separate from the aircraft.

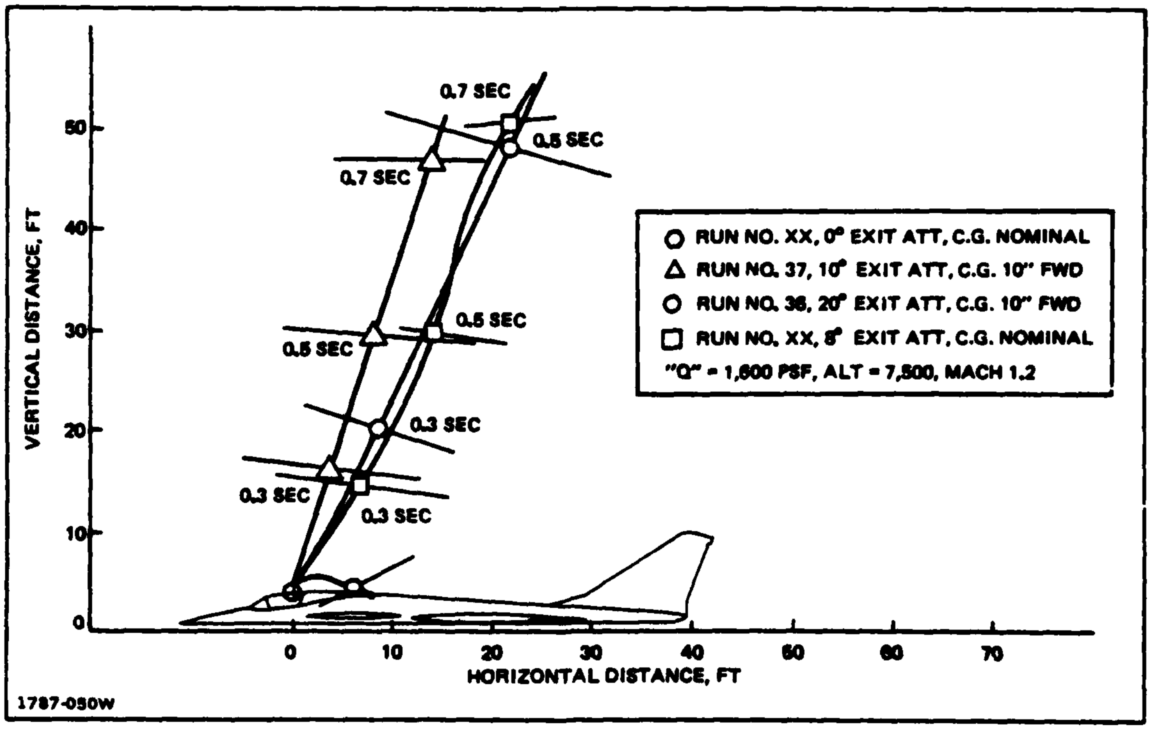


Figure 4-19. Shield/Canopy Trajectories/Exit Attitude Variation

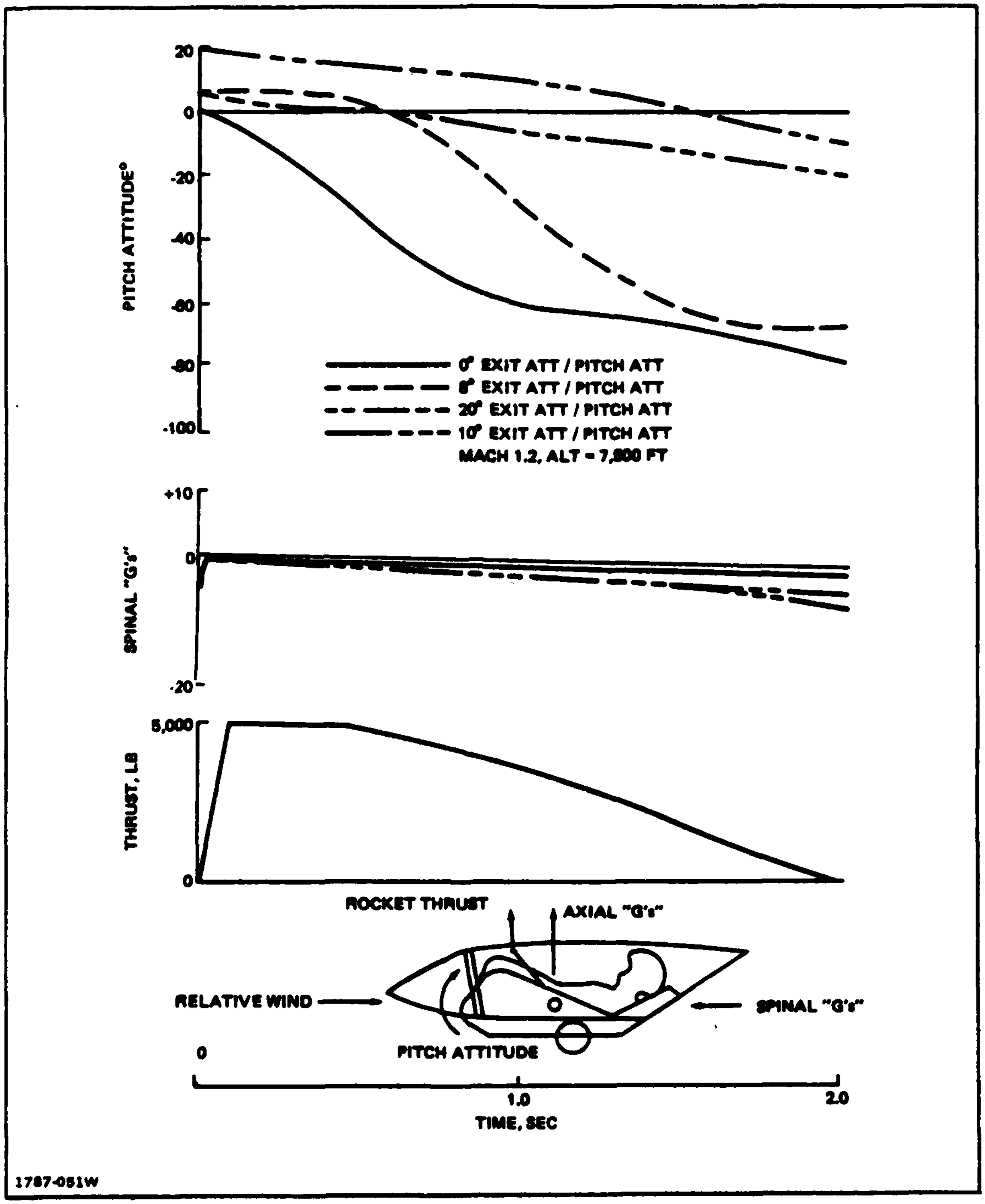


Figure 4-20. Shield/Canopy Time Histories/Exit Attitude Variation

This can be seen more clearly by examining the pitching moment as a function of angle of attack about the shield/canopy CG, as shown in Figure 4-21. The stable trim point for this configuration is approximately -80°. The large negative pitching moment on the shield/canopy as it entered the airstream could not be controlled by the counter moment produced by the rocket through the thrust vector control system.

A second simulation of the shield/canopy is presented in the same flight conditions with a launch attitude of +8° relative to the aircraft at seat separation. With the rocket control system attitude command set to maintain the 8° attitude, the shield/canopy pitched nose-down at a slower rate than the previous run. A positive angle of attack was maintained for approximately 0.6 second. The seat continued to pitch down until it stabilized at approximately -70°. This ejection, however, was successful in separating from the aircraft and clearing the aircraft structure. The success can be attributed to the positive angle of attack during the initial phase of the ejection, at which time substantial lift was generated on the body.

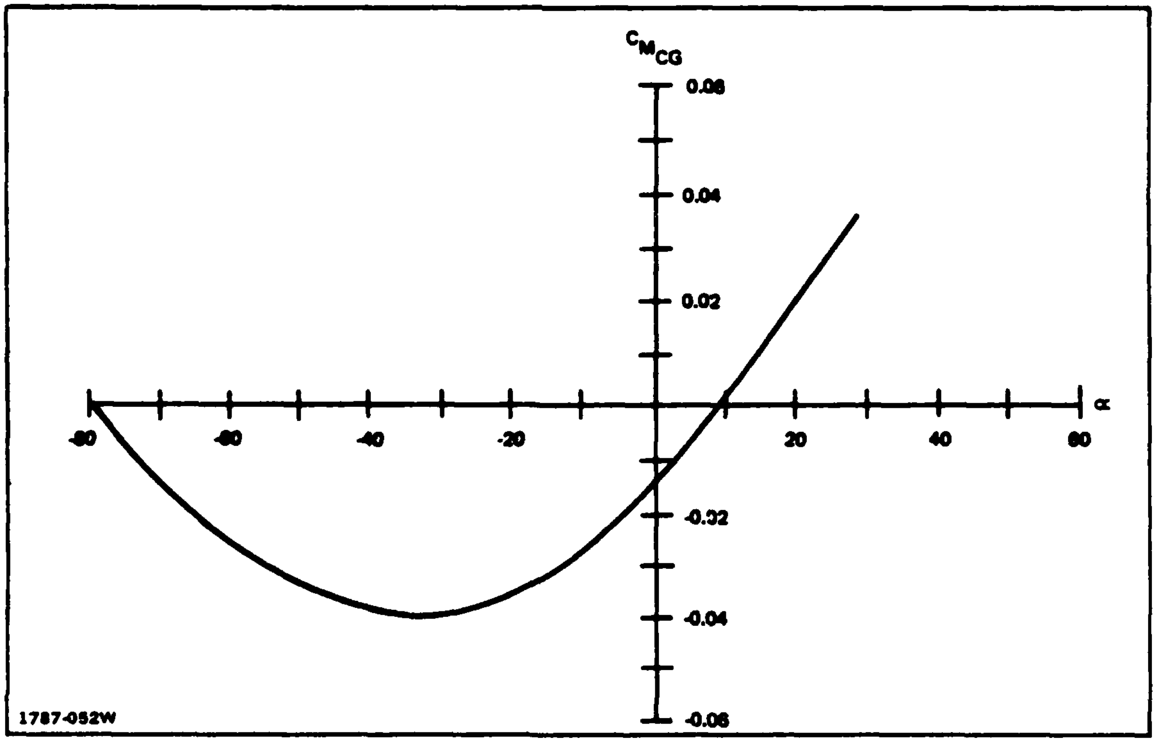


Figure 4-21. Shield/Canopy Pitching Moment vs Angle of Attack

Concern for the substantial pitching motion observed at high dynamic pressure conditions and the severe negative aerodynamics trim point associated with this configuration led to a study of the effects of CG location and launch attitudes. The pitching moment as a function of angle of attack was calculated for various CG locations and the results are shown in Figure 4-22. The CG was located 2 inches, 5 inches, and 10 inches forward of the original location. The results increased the angle of attack of the stable trim point as the CG moved forward.

Numerous trajectory calculations were made varying both the CG location and the launch attitude of the shield/canopy, to determine how sensitive the trajectories were to these parameters. Also presented are the trajectory and time history results for two shield/canopy ejections at Mach 1.2, an altitude of 7500 feet, and a "q" of 1600 psf. The CG for both configurations is located 10 inches forward of the nominal CG. The ejections were launched at 10° and 20° positive attitudes with respect to the aircraft. Both trajectories were satisfactory in that the aircraft tail was cleared and the spinal G on the crewmen were within tolerable limits. The shield/canopy with the 10-inch forward CG

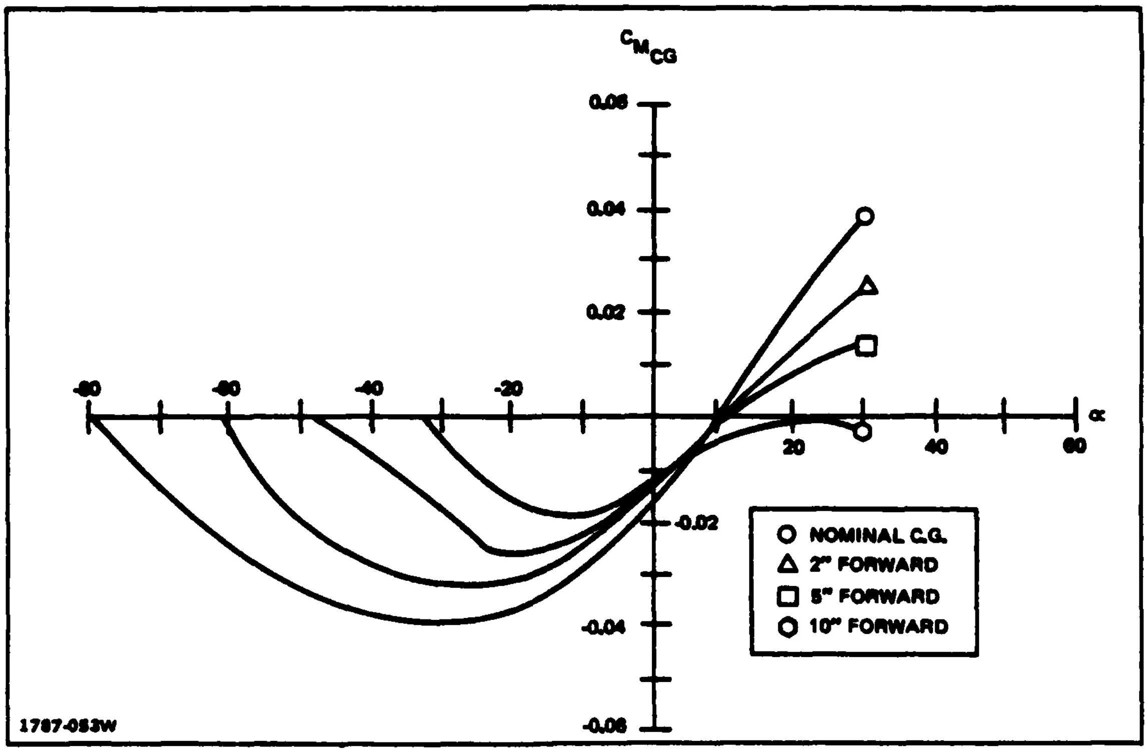


Figure 4-22. Shield/Canopy/Effect of CG Variation on Pitching Moment

achieved attitudes less negative than those for the nominal CG. The deceleration forces for the shield/canopy configuration were less than those for the curved track seat because of the lower drag profile at the ejection angles of attack.

It should be noted that the lower deceleration forces will allow for more flexibility in the rocket orientation and the initial launch attitude. The full 30° thrust component is not required for spinal G reduction, and the launch attitude can be reduced if the rocket is oriented closer to the vertical.

The shield/canopy concept can be actively controlled, and with the proper design can be stabilized at the desired attitude. The critical requirement appears to be a positive launch attitude to insure tail clearance. Additional effort is required to establish the proper CG location and the rates and displacements required at launch for a successful separation throughout the flight envelope. Stabilization in yaw will present additional requirements which are equally severe.

4.4.4 Conclusions

- Active stabilization is necessary for the curved track and shield/canopy concepts.
- Attitude positioning is required for the curved track concept to provide wind blast protection.
- The "B" seat variant concept demonstrated adequate stability in the pitch plane for the limited conditions examined. The influence of CG shifts and seat launch dynamics would influence this conclusion and must be examined further before a definitive conclusion can be made. Yaw stability was not investigated and, if adequate levels are not available from the booms, it might seriously compromise this concept.
- Attitude control is required for the shield/canopy concept to insure adequate tail clearance.
- Extensive ballasting of the shield/canopy concept is necessary to move the CG forward sufficiently to provide a controllable level of stability.

- Thrust orientation of approximately 30° forward of the vertical was found to be a convenient way of relieving spinal accelerations on the curved track and "B" seat concepts. A more nearly vertical orientation which will increase spinal accelerations can be traded off against improved tail clearance and reduced seat rocket thrust levels at high speed or improved trajectory height in low altitude dives.

- Simulation studies, not shown, reveal that a seat rocket with approximately a 2.0-second duration is required for recoveries from adverse attitudes with Vertical Steering Control.

- A rocket thrust time history with a peak level of 5000 pounds and a burning time of approximately 2.0 seconds was sized to satisfy control power levels for attitude control and stabilization, as well as tail clearance requirements at high speed. A burn time of 2.0 seconds is also required for recoveries at low altitude adverse attitude with Vertical Steering Control.

- Control power requirements as determined by thrust deflection angles and thrust levels for both the curved track and "B" seat concepts are within the capability of practical Thrust Vector Control and Vertical Steering Control systems.

- Thrust levels and duration for stabilization and control at high speed ejection conditions for those concepts requiring Thrust Vector Control are consistent with requirements of Vertical Steering Control at low speeds.

- Additional investigation is required to identify the escape envelope in detail for each concept utilizing Vertical Steering Control at high sink rate, adverse attitude conditions.

- A blended control system with the attributes of Thrust Vector Control above 600 KEAS and the attributes of Vertical Steering Control below 600 KEAS is proposed for those concepts requiring active stabilization.

4.4.5 Preferred Concept Selection

The configuration tradeoffs (Tables 3-8 and 3-9) reveal an identical score for the "curved track" and "supine concept" in the size/cost/risk parameters, but show divergent results in aircraft hardware and escape system hardware complexities. The "curved track" system suffers the penalty of seat positioning and separation hardware while the "supine concept" impacts vehicle design in the implementation of windshield, canopy, and instrument panel jettison. However, to the extent that the "supine concept" air vehicle complexity would be necessary to facilitate ingress/egress, the rating of this concept is improved.

In the escape concept performance tradeoffs, the supine concept scores best in projecting the following advantages:

- Earlier clearance of the aircraft ejection envelope
- Direct separation path-seat reposition not required
- Ejection acceleration force applied eyeballs-in
- Ample tail clearance.

The results of the escape concepts evaluation and analysis indicate "supine concept" to be the preferred concept for the maximum performance envelope.

4.5 INTERMEDIATE PERFORMANCE ENVELOPE

The crew escape system concepts developed earlier for compatibility with MSLPC provided safe escape within the performance envelope of 0 to 687 KEAS (1600 psf dynamic pressure) which is identified as the maximum performance envelope. The investigation was extended to include the definition and evaluation of MSLPC compatible escape system concepts which have a capability for intermediate performance envelopes defined by the speed ranges of 0 to 450 KEAS and 0 to 600 KEAS.

4.5.1 Candidate Concepts

For the extended investigation, the intermediate performance baseline candidates (Table 4-1) were selected from a screen of maximum performance concepts, in as much as they have been identified as ejection-type escape systems

TABLE 4-1. INTERMEDIATE PERFORMANCE CANDIDATE BASELINE CONCEPTS

CONCEPT	PERFORMANCE FIT 450 KEAS	PERFORMANCE FIT 600 KEAS	REMARKS
DEFLECTION WEDGE-UPRIGHT	NO	NO	WINDBLAST PROTECTION CONCEPT
DEFLECTION WEDGE-RECLINE	NO	NO	ESCAPE SYSTEM COMPLEXITY
TRACTOR ROCKET	YES	YES	AERO INPUTS FROM EA68 PROGRAM GOOD LOW SPEED PERFORMANCE
CURVED TRACK	YES	YES	GOOD PERFORMANCE
SHIELD/CANOPY	NO	NO	ESCAPE SYS. COMPLEXITY, WINDBLAST PROTECTION CONCEPT
"B" SEAT VARIANT	NO	NO	ESCAPE SYSTEM COMPLEXITY
SUPINE CONCEPT	YES	YES	GOOD PERFORMANCE ALL SPEEDS AIRCRAFT COMPLEXITY
1787-054W			

compatible with MSLPC. The baseline concepts are accordingly identified as the tractor rocket, curved track, and supine concepts. The intermediate performance candidate concept configurations were derived from a functional elements matrix (Appendix C). An ejected weight summary of the candidate configurations is shown in Table 4-2. The principal elements of the configurations are shown in Tables 4-4 and 4-5.

4.5.2 Escape System Cost

The following procedure was used to determine delta costs (Table 4-3) for the candidate intermediate performance escape system concepts:

- A matrix of all systems with the components required for each system was established
- Components not used on all systems were priced
- Price estimate was based on reasonable total production of 500 units with reasonable yearly deliveries of 72 units
- Cost for each system was determined by summing the cost of all unique components
- The lowest cost system was established as the baseline.

Although the curved track and supine concept escape systems are similar once separated from the aircraft, the higher cost deltas of the supine system

TABLE 4-2. ESCAPE CONCEPTS EJECTED WEIGHT SUMMARY, LB

COMPONENTS \ ESCAPE SYS CONCEPT	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED CONCEPT
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	
SEAT:													
ROCKET	22	39	19.5	39	19.5	39	22	39	19.5	39	19.5	39	39.0
PROPELLANT	6	15	6.5	15	6.5	15	6	15	6.5	15	6.5	15	15.0
SEAT STRUCTURE	117	117	108	110	108	110	117	117	108	110	108	110	110.0
HARNESS RETRACTOR	5	5	5	5	5	5	5	5	5	5	5	5	5.0
HARNESS, BELT, & CUSHIONS	14	14	14	14	14	14	14	14	14	14	14	14	14.0
SEAT MECHANISM	8	8	8	8	8	8	8	8	8	8	8	8	8.0
INITIATION & SEQUENCE	10	10	7	7	7	7	10	10	7	7	7	7	7.0
MISC (UP SEEKING)	–	4	–	4	–	4	–	4	–	4	–	4	4.0
SURVIVAL KIT	38	38	38	38	38	38	38	38	38	38	38	38	38.0
CREW WEIGHT:													
5 PERCENTILE PILOT	140.2		140.2		140.2		140.2		140.2		140.2		140.2
95 PERCENTILE PILOT	210.8		210.8		210.8		210.8		210.8		210.8		210.8
DROGUE	–	–	7	7	7	7	–	–	7	7	7	7	7.0
RECOVERY PARACHUTE	20	20	20	20	20	20	20	20	20	20	20	20	20.0
PERSONAL EQUIP, 5%	20.0		20.0		20.0		20.0		20.0		20.0		20.0
PERSONAL EQUIP, 95%	43.2		43.2		43.2		43.2		43.2		43.2		43.2
TOTAL EJECTED WT, 5%	400.2	430.2	393.2	427.2	393.2	427.2	400.2	430.2	393.2	427.2	393.2	427.2	427.2
TOTAL EJECTED WT, 95%	494.0	524.0	487.0	521.0	487.0	521.0	494.0	524.0	487.0	521.0	487.0	521.0	521.0

NOTES: STD = STANDARD; FR = FIXED ROCKET; VS = VERTICAL STEERING.

1787-055W

TABLE 4-3. ESCAPE SYSTEM COST DELTAS
(1979 DOLLARS – REASONABLE PRODUCTION, NO RDT&E OR PROTOTYPES)

0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED CONCEPT
STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	
BASELINE = $42,000	+16,950	+1,075	+17,025	+20,675	+36,525	+1,175	+17,900	+1,250	+17,025	+20,750	+36,525	+40,375

NOTES: STD = STANDARD; FR = FIXED ROCKET; VS = VERTICAL STEERING.

1787056W

are due to associated windshield, canopy, instrument panel, and structural complexities.

The development costs for the tractor rocket system, established as the baseline, is estimated to be \$27.0 million, which is approximately equal to current (F-14) escape system development costs in 1979 dollars. The curved track system development, considering such elements as limb restraint and vertical steering components, has a cost factor of about 1.8 that of the baseline, or the equivalent of \$48.6 million.

The supine concept with vertical steering/vector control for 0 to 687 KEAS requires a development cost factor about 1.3 more than the curved track system, or about \$63.2 million. Items that contribute to the increased cost include thrust vector control and components that implement upward separation from the aircraft.

4.5.3 Intermediate Performance Analysis

In so far as the curved track concept and the supine concept present an identical seat/man mass and form factor to the air stream on aircraft separation, the aerodynamic performance analysis was limited to the curved track and tractor rocket concepts.

4.5.3.1 Curved Track Escape Performance - The curved track escape concept performance evaluation was extended to include low speed and adverse attitude escape conditions and high dynamic pressure escape conditions. Additional configurations were examined for escape speeds of 0 to 450 KEAS and 0 to 600 KEAS.

Four candidate system configurations for the curved track seat are identified in Table 4-4 with the pertinent event schedules shown in Table 4-5. The corresponding rocket thrust schedules shown in Figure 4-23 are identified by a letter designation and are those used in the earlier study.

The four systems are identified as Systems I through IV. System I utilizes a fixed seat rocket and is representative of a conventional ejection seat escape system. Systems II and III both employ Vertical Steering Control for directing

TABLE 4-4. SYSTEM CONFIGURATIONS

COMPONENT IDENTIFICATION	SYSTEM I	SYSTEM II	SYSTEM III	SYSTEM IV
ROCKET CONTROL SYSTEM	NONE (FIXED ROCKET)	VSC	VSC	VSC/TVC
SEAT ROCKET TYPE	A	B	C	C
DROGUE DIAMETER	5 FT	4 FT	2 FT	2 FT
MAIN PARACHUTE DIA	28 FT	28 FT	28 FT	28 FT

NOTES: VSC = VERTICAL STEERING CONTROL; TVC = THRUST VECTOR CONTROL.

1787-057W

TABLE 4-5. ESCAPE EVENT SCHEDULE

EVENT	ELAPSED TIME (SEC)		
	SYSTEM I	SYSTEM II	SYSTEM III, IV
SEAT-A/C SEPARATION	0	0	0
ROCKET INITIATION	0	0	0
DROGUE INITIATION (V > 250 KEAS OR ALT > 15,000 FT)	0.10	1.6	1.505
DROGUE LINE STRETCH	0.18	1.68	1.59
ROCKET BURNOUT	0.265	1.75	2.0
MAIN CHUTE DEPLOYED (ALT < 15,000 FT)	0.9	3.15	3.35
MAIN CHUTE LINE STRETCH	1.8	4.4	4.6

1787-058W

the seat into an earth oriented up trajectory, but use different size seat rockets. The variation in rocket sizes for these systems was chosen to show the effect of rocket thrust on the escape performance. System IV utilizes Vertical Steering Control below 600 KEAS with Thrust Vector Control for attitude positioning at speeds above 600 KEAS. System IV is the configuration defined earlier for the 0 to 687 KEAS speed range. In this phase, System IV performance is verified more completely below 600 KEAS. Systems I, II, and III are configured specifically for the speed ranges of 0 to 450 KEAS and 0 to 600 KEAS. Systems III and IV perform identically below 600 KEAS since they both utilize Vertical Steering Control in this speed range. However, only System IV operates above 600 KEAS.

All system configurations utilize a 28-foot flat circular main parachute (Table 4-4). Drogue parachute size varies with each configuration. System I

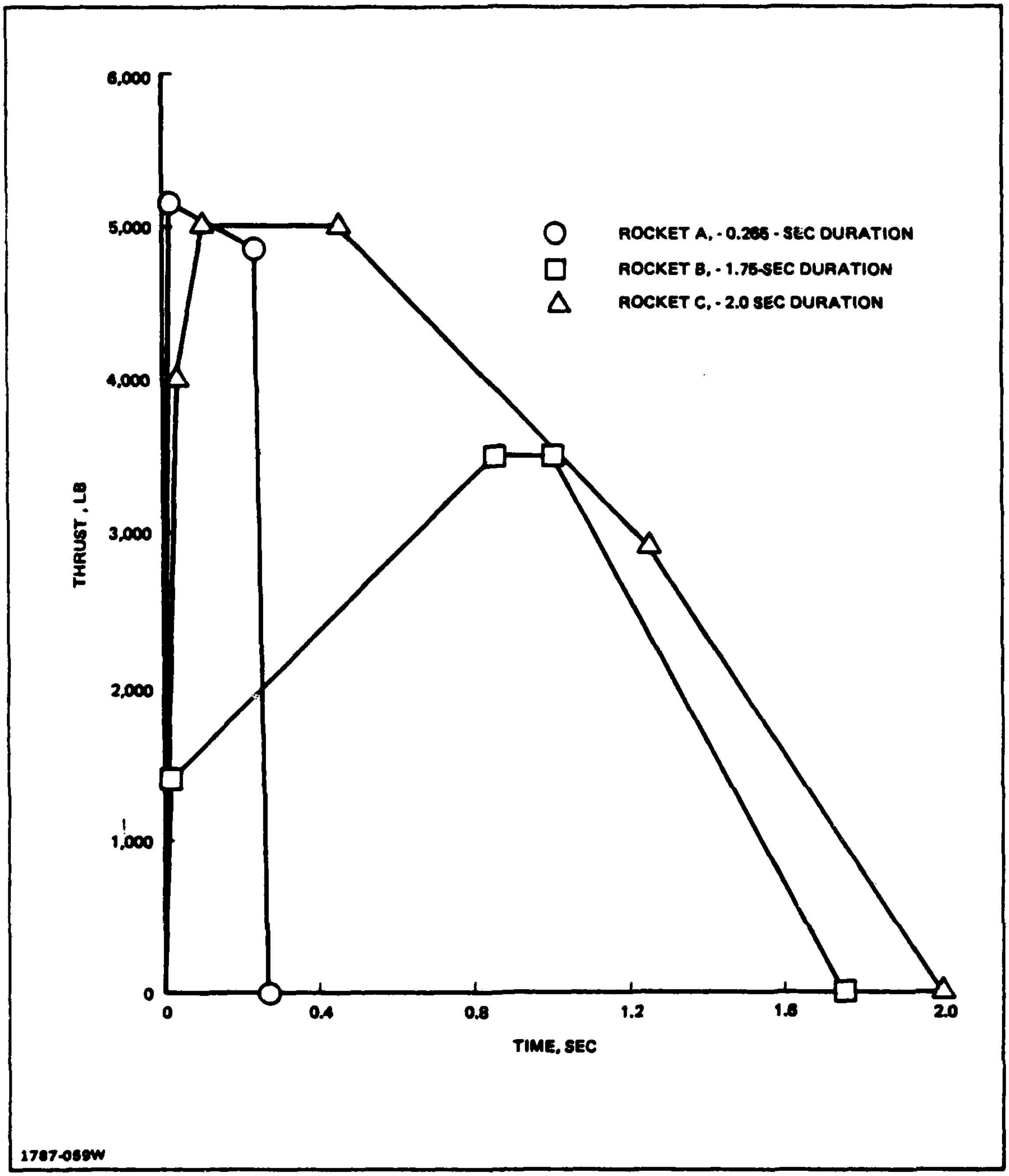


Figure 4-23. Rocket Thrust Time History

AD-A081 055 GRUMMAN AEROSPACE CORP BETHPAGE NY F/G 1/3
INVESTIGATION OF MINIMUM SIZED LOW-PROFILE COCKPITS (MSLPC) AND--ETC(U)
SEP 79 W C TAUBY F33615-78-C-3427
UNCLASSIFIED AFFDL-TR-79-3104 NL

2 OF 3
AD
A081055

has a 5-foot diameter, System II has a 4-foot diameter, and System III and IV have 2-foot diameters. For escapes initiated above 250 KEAS or 15,000 feet, the drogue is deployed and, subsequently, the main parachute is deployed after the specified time interval or a descent below 15,000 feet. Below 250 KEAS and 15,000 feet, only the main parachute is deployed. Deployment is in accordance with the escape event schedule (Table 4-5). The main and drogue parachute sizing, sequencing, and timing were chosen to represent reasonable values for the several speed regimes. No attempt was made to modify or optimize values, to improve performance, or to satisfy conflicting requirements.

This study phase differs from the previous investigations in that motions out of the pitch plane were considered. This was determined by the need to extend the performance evaluations of several configurations of the curved track seat with respect to adverse attitude escape conditions. A series of 11 flight conditions were selected, seven of which are the "Low Level Escape Performance" conditions of MIL-S-9479B (USAF), and represent a reasonably severe test of escape system capability. The others are intended to fill out the escape envelopes for each speed range. All the escape conditions are summarized in Table 4-6.

The adverse attitude escape conditions established a requirement for additional aerodynamic data beyond that previously generated for the pitch plane analysis. The data requirements were satisfied using the same analytical procedure as described previously. The results have been tabulated in Table 4-7 and presented as seat/man rolling, yawing moment, and side force coefficients vs side slip angle at zero angle-of-attack. These data supplement the pitch plane data presented earlier.

The Vertical Steering Control system was permitted to command both roll and pitch responses to effect recoveries from an inverted attitude, or to seek a vertical up reference. The system gains and time constants were unchanged and no attempt was made to optimize control system response or improve performance.

A rocket thrust schedule was previously sized for the curved track concept to accommodate control power requirements for seat stabilization and tail clearance at high dynamic pressure escape conditions. This schedule is identified as Rocket C in Figure 4-23. This schedule was evaluated for System IV below 600 KEAS and

TABLE 4-6. FLIGHT CONDITIONS

COND NO.	V, KEAS	γ, DEG	θ, DEG	φ, DEG	R/S FPM	h,* FT	DESCRIPTION
1	0	0	0	0	0	–	ZERO-ZERO
2	120	0	0	60	0	0	60° BANK AT IMPACT WITH GROUND
3	150	–40.4	0	0	10,000	300	LOW SPEED, DESCENT W/WINGS LEVEL
4	450	0	0	0	0	–	WINGS LEVEL
5	600	0	0	0	0	–	WING LEVEL
6	687	0	0	0	0	–	WINGS LEVEL, h = 40K, $\overline{q}$ = 1600 PSF
7	150	0	0	180	0	200	INVERTED, WINGS LEVEL, LOW ALT
8	200	–60	–60	0	17,810	500	LOW SPEED DIVE
9	450	–30	–30	0	23,140	500	MAX SPEED DIVE
10	200	–60	–60	60	17,810	550	LOW SPEED, 60° BANK AND DIVE
11	250	–45	–45	180	18,180	600	MED SPEED, INVERTED DIVE

* MINIMUM ALTITUDE FROM MIL-S-9479B (USAF).

1787-060W

TABLE 4-7. CURVED TRACK CONCEPT, AERODYNAMIC COEFFICIENTS

SIDESLIP ANGLE β, DEGREES	COEFFICIENT C_Y	C_n	C_ℓ
0	0	0	0
30	–0.356	0.0279	–0.0279
60	–1.067	0.0838	–0.0891
90	–1.422	0.1118	–0.1188
120	–1.067	0.0838	–0.0891
150	–0.356	0.0279	–0.0297
180	0	0	0
210	0.356	–0.0279	0.0297
240	1.067	–0.0838	0.0891
270	1.422	–0.1118	0.1188
300	1.067	–0.0838	0.0891
330	0.356	–0.0279	0.0297
360	0	0	0

• AERODYNAMIC REFERENCE POINT AT SRP.

1787-061W

also considered as a candidate for System III. Rocket B was used in System II in an attempt to reduce the rocket size for the 0 to 600 KEAS speed range. A comparison of System II with System III shows this difference. Rocket A represents a typical schedule for a conventional system with an escape speed range from 0 to 600 KEAS.

The fixed rocket thrust orientation and the null position of the rocket thrust vector for the TVC and VSC systems were directed parallel to the seat vertical (Z axis). This differs from the previous study phase where the orientations were 30° forward of the seat vertical axis. The vertical orientation was selected since alleviation of spinal accelerations by this means was not necessary at speeds below 600 KEAS, and it allowed a consistant comparison of the three speed regimes.

Performance results are presented in the form of spatial plots in the X-Z vertical plane. One plot is presented for each condition of Table 4-6, comparing the four systems on each plot where appropriate.

DISCUSSION

The digital computer program (A280B) used for this analysis is similar to the one utilized in the previous study with minor alterations to accommodate the three new curved track concepts or systems. Lateral-directional aerodynamic coefficients have been included in the data package to determine out-of-plane motions and displacements. The control law has been modified and expanded to include simulation of the roll channel in the Vertical Steering Control System.

Each trajectory is initiated at the aircraft exit position. Thus, any translational and rotational rates generated by a seat booster and imparted on the seat/man system are neglected. In general, if the aircraft is in an upright attitude ($\phi < 90^\circ$, $\phi > -90^\circ$) at system initiation, the trajectory obtained in the analysis (without the booster) will be conservative. Hence, in runs where the results are marginal, the system may still be qualified using the booster. However, the minimum altitude attained for the inverted attitude cases may be higher if the booster is included.

The results of the analysis are presented as a summary of performance characteristics (Table 4-8) for each of the 11 conditions. The G levels (spinal (X), side (Y), and axial (Z)) are the peak accelerations imposed on the crewman in the seat/man body axis system during the escape sequence while the

TABLE 4-8. SECOND PHASE, PERFORMANCE MATRIX

COND NO.	G_X (SPINAL)			G_Y (SIDE)			G_Z (AXIAL)			STABILITY			TAIL CLEARANCE			MIN ALT IN TRAJ			PEAK ALT IN TRAJ		
	SYS I	SYS II	SYS III, IV	SYS I	SYS II	SYS III, IV	SYS I	SYS II	SYS III, IV	SYS I	SYS II	SYS III, IV	SYS I	SYS II	SYS III, IV	SYS I	SYS II	SYS III, IV	SYS I	SYS II	SYS III, IV
1	0	0	0	0	0	0	10.6	7.0	10.2	√	√	√	√	√	√	791	0	0	84	585	1093
2	−0.4	−0.7	−1.1	0	0	−0.1	10.4	7.0	10.0	√	√	√	√	√	√	56	0	0	17	461	962
3	−0.2	−0.5	−0.5	0	0	0	11.2	6.0	10.7	√	√	√	√	√	√	325	224	50	0	0	444
4	−7.5	−4.7	−4.7	0	0	0	8.6	5.0	8.1	√	√	√	√	√	√	69	0	0	22	153	548
5	−8.3	−8.3	−8.3	0	0	0	7.2	4.0	6.4	√	√	√	√	HIT	√	66	–	0	12	–	345
6	–	–	−10.8	–	–	0	–	–	5.5	–	–	√	–	–	√	–	–	0	–	–	–
7	−0.7	−0.6	−0.6	0	1.1	2.8	10.3	6.9	10.0	√	√	√	√	√	√	256	21	22	0	148	335
8	−1.1	−0.9	1.9	0	0	0	10.2	8.1	10.9	√	√	√	√	√	√	634	774	312	0	0	0
9	−4.8	−4.5	−4.4	0	0	0	8.6	9.4	10.9	√	√	√	√	√	√	613	902	534	0	0	0
10	−1.1	−0.9	1.9	0.4	0.6	1.1	10.2	8.1	11.0	√	√	√	√	√	√	664	803	374	0	0	0
11	−1.5	−1.3	−1.2	0	1.4	1.8	10.0	8.5	11.3	√	√	√	√	√	√	704	993	758	0	0	0
1787-062W																					

rocket is thrusting. The highest value in the table is 11.3 G in the axial direction. These are low compared to the accelerations normally experienced during parachute deployments. In fact, the analysis indicates that the decelerations due to main parachute openings are on the order of 20 G or more. However, the durations are very short. The G levels obtained with the computer simulation of the parachute systems represent levels for conventional parachutes at normal parachute and drogue opening speeds.

Stability analysis of the seat system was a qualitative process since no mathematical expression or guideline was used to determine the stability level, whether statically or dynamically. The check mark (√) in these columns and the columns for tail clearance indicates adequate levels were achieved. A "hit" in the tail clearance column indicates possible contact of the seat/man with the vertical tail of the aircraft. A nominal tail height of 10 feet, displaced 40 feet horizontally from the ejection initiation point, was used as the criterion. Minimal altitude was the lowest altitude of the aircraft above ground level for a safe ejection. The minimum altitude usually corresponded to either the altitude required to reach a safe terminal velocity under a full main parachute canopy (total velocity of man of 30 fps and vertical component of the velocity vector of 24 fps) or the lowest point in the trajectory. A zero for minimal altitude can be interpreted to mean that ejection was successfully initiated at ground level. The peak altitude values are simply points on the apex of the trajectory. A zero indicates that the seat/man system could not achieve the initial ejection altitude.

With regard to the plots shown in Figures 4-24 to 4-34, the escape sequence for all the flight conditions except No. 6 was initiated at an arbitrary altitude of 1000 feet. This was done to accommodate the computer simulation to prevent escape trajectories from going below ground level. The aircraft was positioned at a height of 1000 feet to insure that none of the trajectories would exceed a downward displacement of 1000 feet prior to attaining a terminal velocity.

The following is a brief discussion of each run. Any peculiar or unique characteristics are mentioned, and suggestions are made to alleviate or remedy possible problems or to improve the overall system performance. Flight

conditions are given in Table 4-6, rocket designations in Figure 4-23, X vs Z coordinate plots in Figures 4-24 to 4-34.

Flight Condition 1 (Figure 4-24)

System I: The fixed seat rocket, with a burn time duration of 0.265 second (Rocket A) propelled the seat/man mass to a maximum height of 84 feet; the fall from the peak point before terminal velocity was approximately 800 feet, which resulted from (1) the lack of an initial ejection velocity normally imparted by a seat booster, and (2) a delayed parachute deployment time. The employment of a booster would have allowed the seat/man system to reach a higher peak altitude, thus decreasing the distance of the fall before a safe deceleration had occurred.

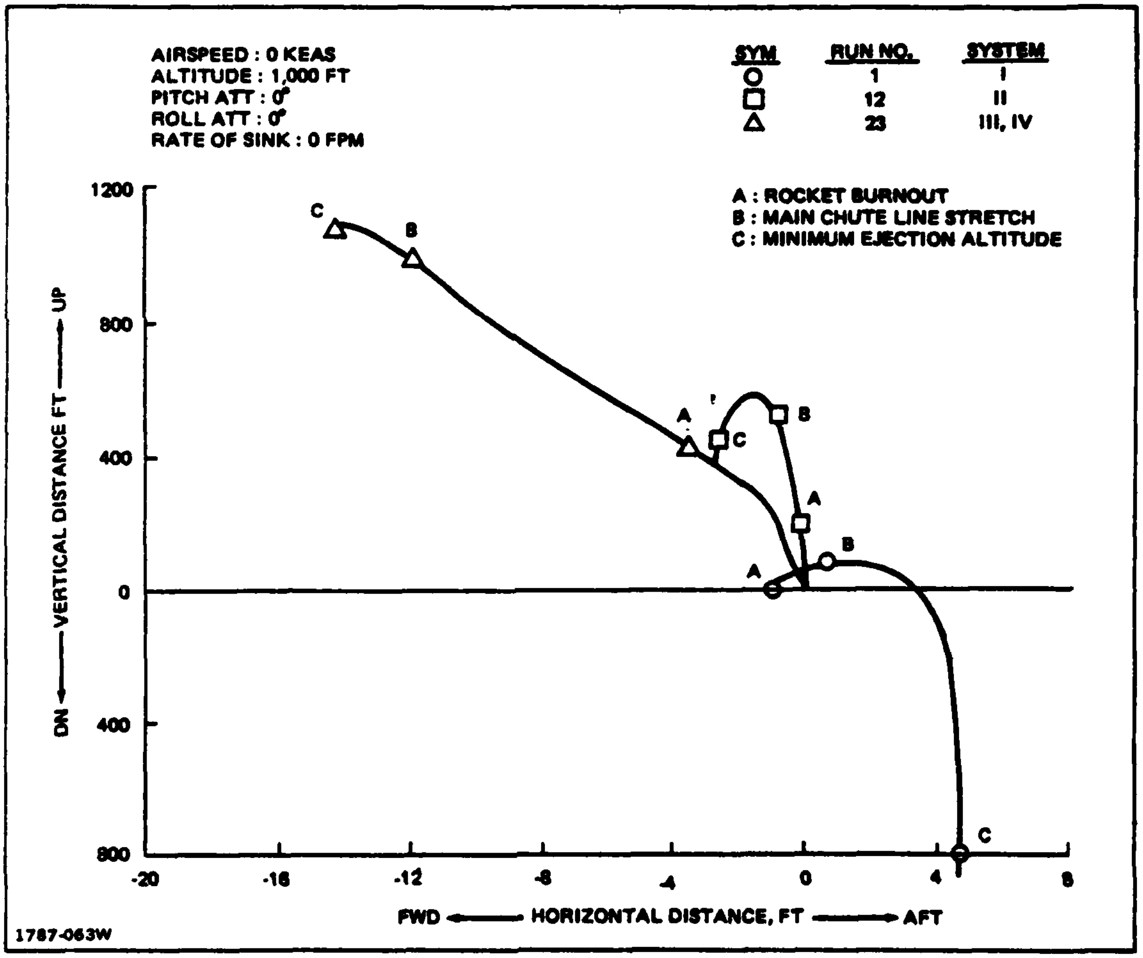


Figure 4-24. Escape Trajectories, Flight Condition 1

The parachute was designed to be fully opened at 1.8 second subsequent to system separation from the aircraft. For this flight condition, however, this event occurred just prior to the seat/man reaching trajectory apex where the airspeed is near zero. This resulted in a delayed parachute inflation which also delayed deceleration of the crewman during the descent. Earlier parachute deployment in the ascent phase, where the velocity is higher, would have permitted full inflation at the apex of the trajectory and, combined with the seat booster velocity, would probably have met the zero-zero condition.

There was no G forces in the X (spinal) or Y (side) directions on the man during rocket thrusting; the peak axial G (in the Z direction) was an acceptable 10.6.

Since there was no control system for this seat configuration, the rocket thrust vector was fixed through the CG of the seat/man, which resulted in practically zero rotation about all three axes.

System II: No problems were encountered. The longer burning rocket resulted in a much higher trajectory. The peak altitude reached was 585 feet above the ejection point, while terminal speed was attained 449 feet above ejection altitude. The 7G experience in the axial direction was acceptable. Rotational rates were low. A minimum escape altitude of zero feet was achieved.

Systems III & IV: In as much as the escape condition is below 600 KEAS, the trajectories for Systems III and IV are identical. The higher impulse rocket (Rocket C) powered the man/seat system to a peak altitude of 1083 feet. A peak axial G of 10.2 was obtained during rocket burn. Both systems meet the zero-zero escape requirement.

Flight Condition 2 (Figure 4-25)

System I: The analysis shows that this system does not appear to meet the MIL-S-9479B requirement of zero feet minimum altitude. The trajectory indicates that a height of only 17 feet was reached and a fall of 55 feet below the ejection altitude was sustained before a satisfactory sink rate was achieved. The addition of booster end conditions would not appreciably increase the peak altitude for a safe parachute recovery above the ejection altitude, since the trajectory is inclined 60° to the horizontal.

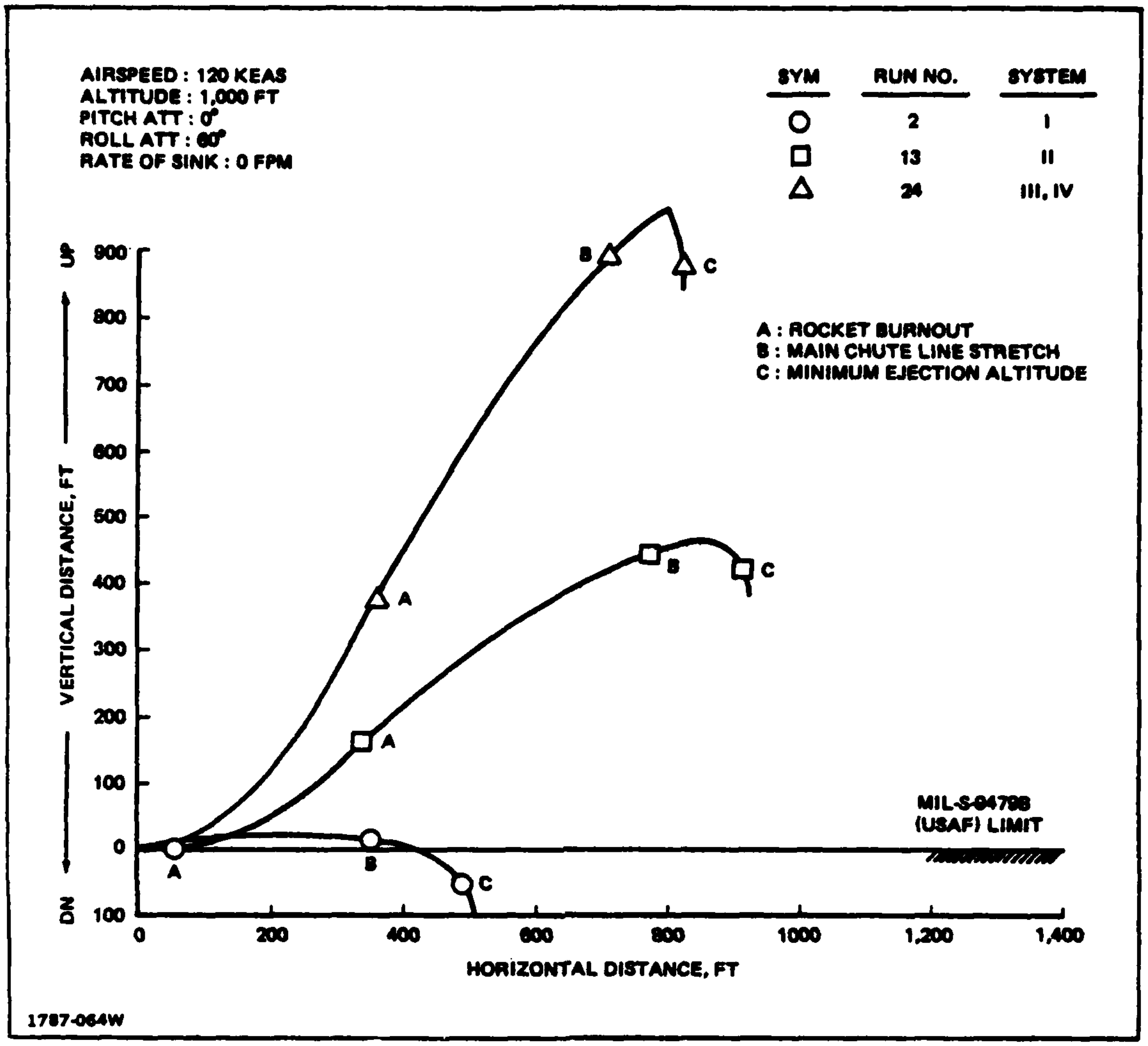


Figure 4-25. Escape Trajectories, Flight Condition 2

System II: The MIL SPEC requirements were satisfied and G levels were tolerable. The Vertical Steering Control system supplied the appropriate roll command to restore the seat/man system to an upright attitude with little overshoot. The peak altitude reached was 461 feet. Minimum ejection altitude was zero feet.

Systems III & IV: The output from the autopilot rapidly restored the systems to an upright position; the additional rocket thrust and burn duration enabled the systems to achieve a peak of 962 feet from a ground level ejection.

Flight Condition 3 (Figure 4-26)

System I: The analysis showed that an altitude of 325 feet was required to reach a safe terminal speed under the main parachute compared with the MIL SPEC limit of 300 feet. A booster exit velocity would adequately compensate for the altitude difference required to meet the specification requirement. The tail clearance was over 100 feet.

System II: An altitude of 224 feet was needed for a safe recovery. The clearance of the tail of the aircraft was over 200 feet.

Systems III & IV: The altitude loss below the ejection altitude was only 50 feet. The higher thrust rocket for these systems enabled the seats to ascend to a height of 444 feet above the initial altitude. Terminal descent speed under a fully deployed main parachute was reached 300 feet above the initial escape altitude.

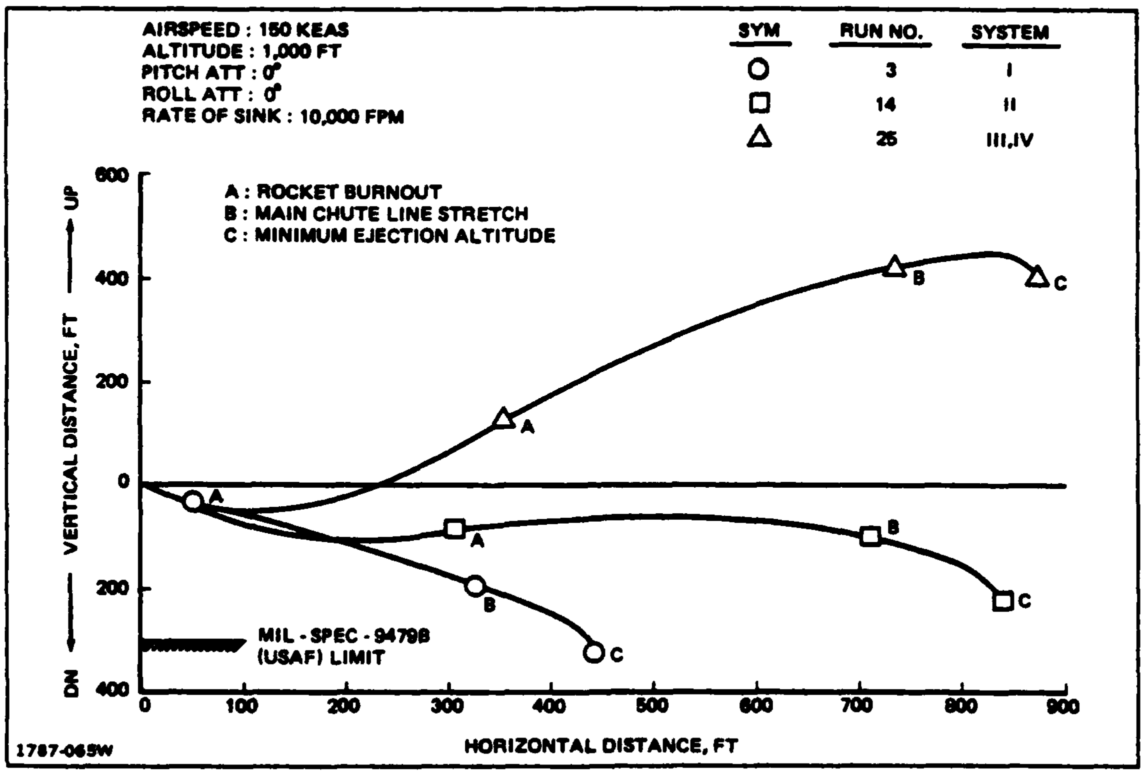


Figure 4-26. Escape Trajectories, Flight Condition 3

Flight Conditions 4, 5, 6 (Figures 4-27 to 4-29)

The emphasis, in these three flight conditions, was on the capability of each system to clear the aircraft. Flight conditions 4 and 5 were at medium high speed (450 and 600 KEAS, respectively) and flight condition 6 was a high dynamic pressure ("q" = 1600 psf), high speed (687 KEAS) case.

System I: The tail clearances for flight conditions 4 and 5 were marginal; this, however, could be much improved with the incorporation of seat booster end conditions. The minimum ejection altitude required to reach a safe parachute terminal speed was 69 feet for flight condition 4, and 66 feet for flight condition 5. The spinal and axial G due to rocket thrust were tolerable. Flight condition 6 was not analyzed since this system does not apply to this range because it does not provide attitude control for wind blast protection. The spinal and axial G due to the rocket were tolerable.

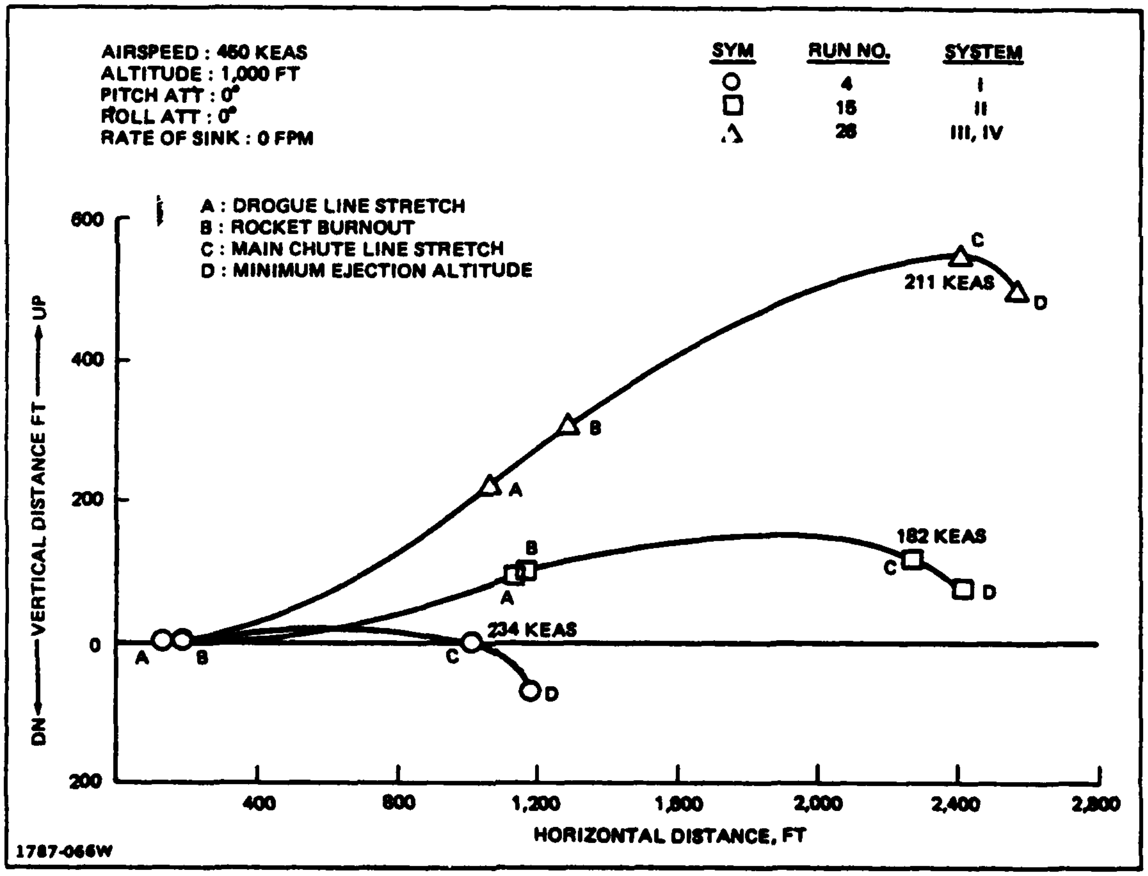


Figure 4-27. Escape Trajectories, Flight Condition 4

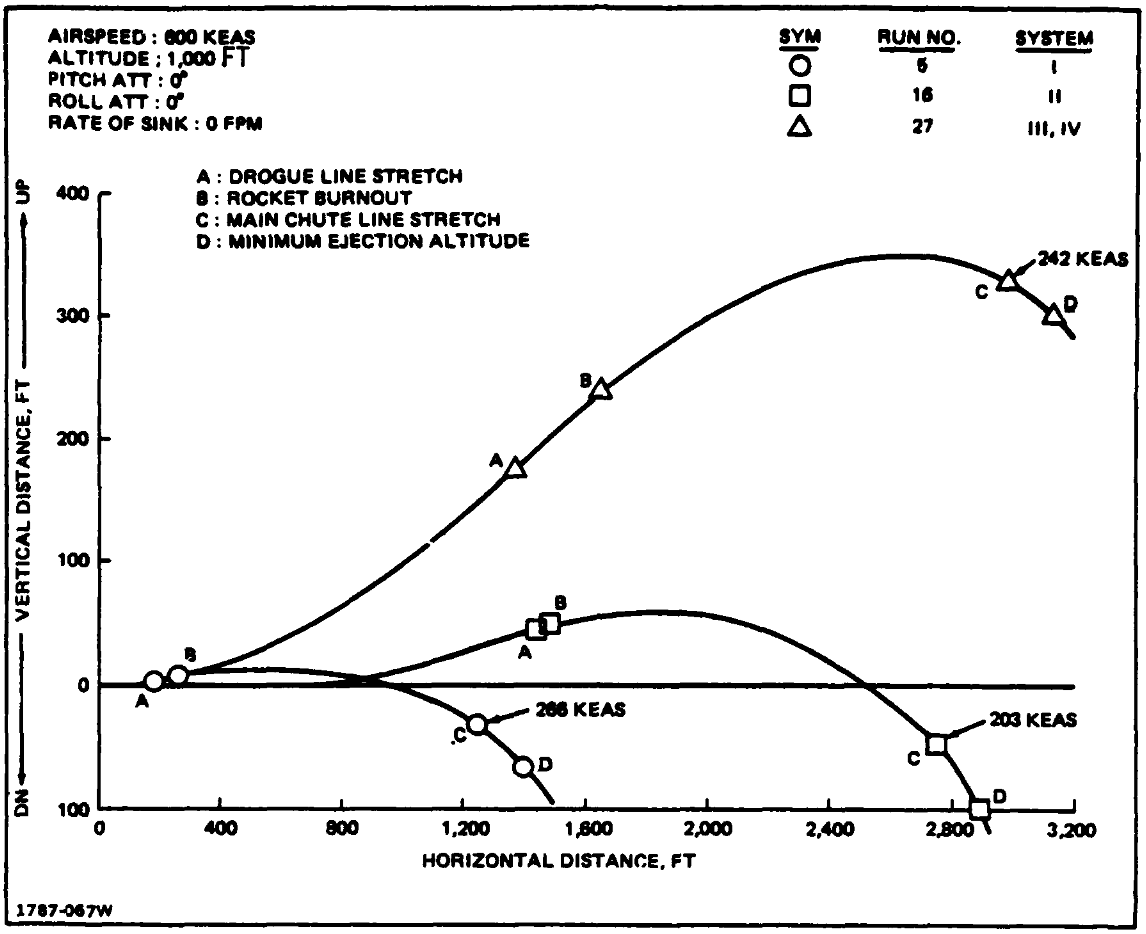


Figure 4-28. Escape Trajectories, Flight Condition 5

System II: The tail clearance for flight condition 4 was marginal due to the lower initial thrust of Rocket B. In the trajectory for flight condition 5, a tail strike was indicated. It is questionable whether the addition of booster end conditions would provide sufficient additional thrust to provide adequate tail clearance. Spinal and axial G were within tolerance. Flight condition 6 was not analyzed since the earlier study had already disqualified System II at this speed.

Systems III & IV: The performance for both systems was identical for flight conditions 4 and 5, with more than adequate tail clearance. This was due to the high initial thrust produced by Rocket C and the longer burning time. For flight condition 6, however, where the dynamic pressure was about 1600 psf, System III is inappropriate since a Vertical Steering Control System would not maintain a fixed seat attitude to prevent wind blast and limb flailing. Pre-

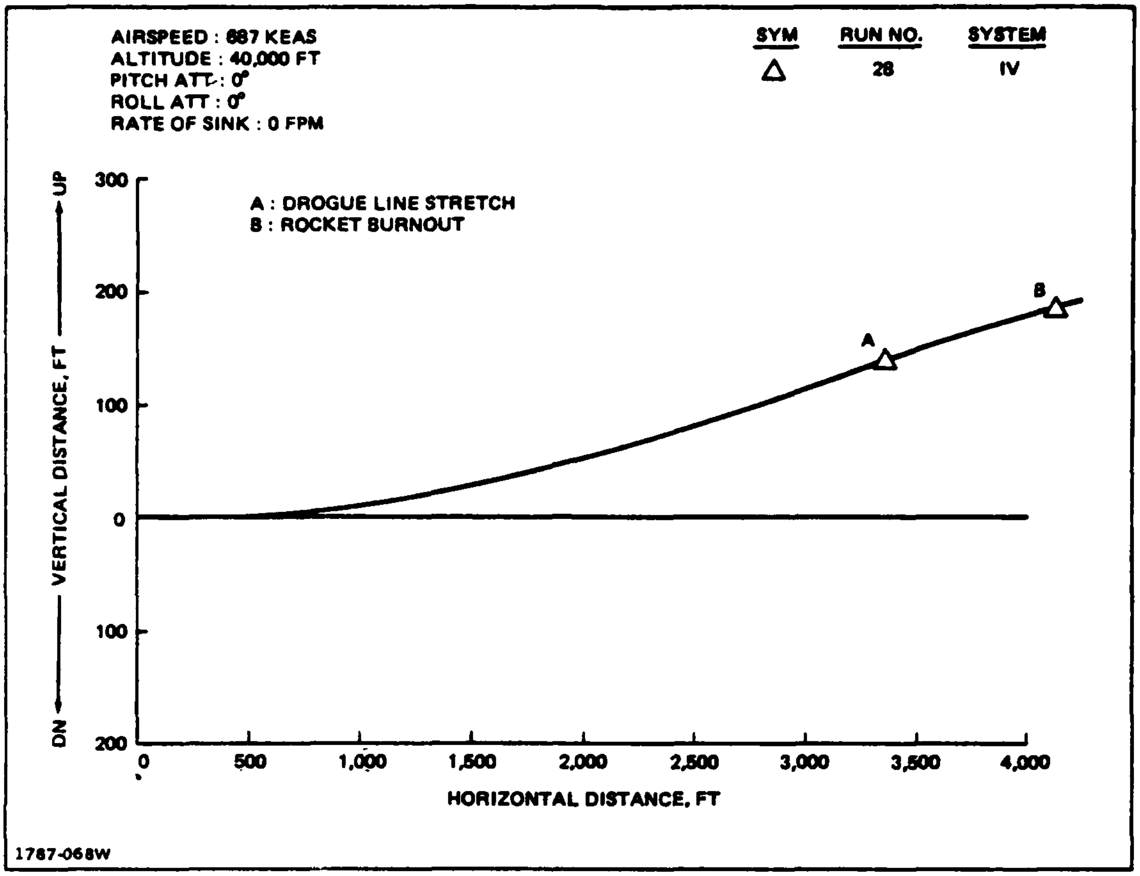


Figure 4-29. Escape Trajectories, Flight Condition 6

vious analysis identified System IV as the more viable one for speeds above 600 KEAS, since the Thrust Vector Control mode is capable of maintaining the seat/man in a streamlined attitude. The earlier analysis for the 687 KEAS case is repeated for comparison purposes.

Flight Condition 7 (Figure 4-30)

System I: The fixed rocket maintained the seat/man along a trajectory of decreasing altitude until the main parachute was fully deployed. The minimum escape altitude attained was 250 feet, which does not meet the MIL SPEC limit of 200 feet. A seat booster would probably hurt the performance further since the additional momentum provided by the booster would be in the downward direction. However, it can be seen that the main chute line stretch occurred over 150 feet below initial altitude. If the timing for the main chute deployment was advanced, the performance might be improved sufficiently to meet the specification requirement.

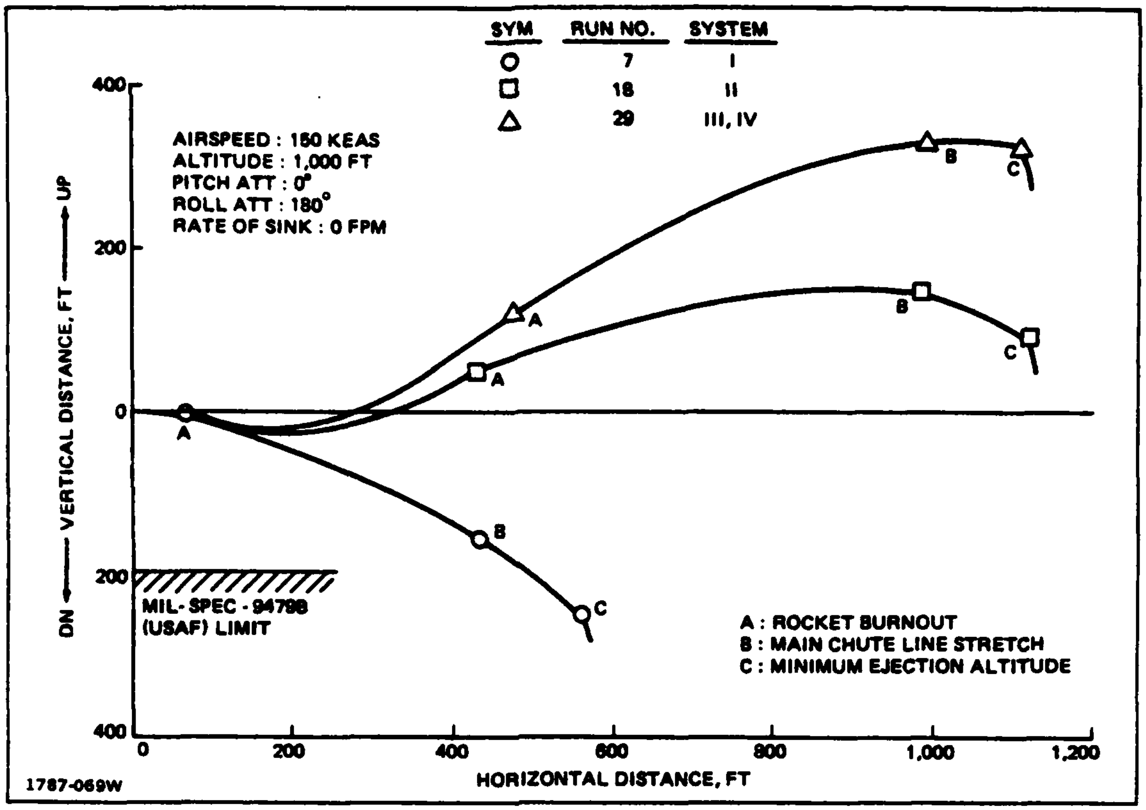


Figure 4-30. Escape Trajectories, Flight Condition 7

System II: Subsequent to ejection from the aircraft, the system displaced the seat/man downward only 21 feet before the roll command from the autopilot restored an upright attitude and stopped the descent. The system reached a peak altitude of 148 feet above escape initiation. In addition to spinal G of -0.7 and axial G of 10.3, there was also a side G of 1.1 due to the rolling motion in the recovery.

Systems III & IV: The peak altitude attained was 335 feet above initial altitude. The G levels for the side and axial directions (2.8 and 10.0, respectively) were tolerable.

Flight Condition 8 (Figure 4-31)

System I: The minimum altitude for escape was 634 feet; the MIL SPEC limit is 500 feet. The figure shows that the main chute was not fully deployed until the system had traveled 500 feet downward. An earlier main chute

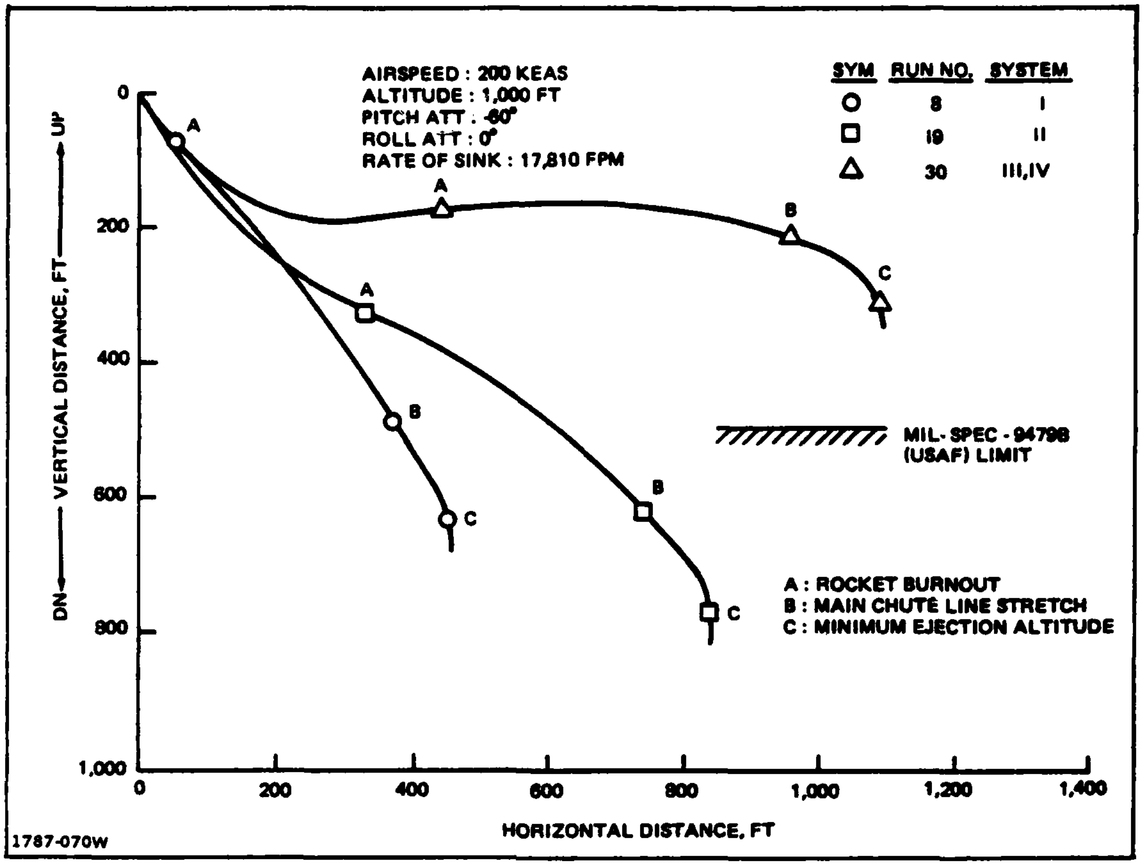


Figure 4-31. Escape Trajectories, Flight Condition 8

deployment might improve the system to meet the spec requirement. Booster end conditions would also enhance the performance.

System II: Poor performance results from inadequate thrust from the seat rocket, together with the long delay before main chute deployment. The minimum altitude was 774 feet which exceeds the MIL SPEC limit of 500 feet.

Systems III & IV: The additional thrust from Rocket C combined with the parachute drag decreased the rate of descent of the system sufficiently to meet the specification limit. The minimum ejection altitude was 312 feet.

Flight Condition 9 (Figure 4-32)

System I: The figure shows that MIL SPEC limit minimum altitude was not met. An earlier main chute deployment would exceed the parachute inflation

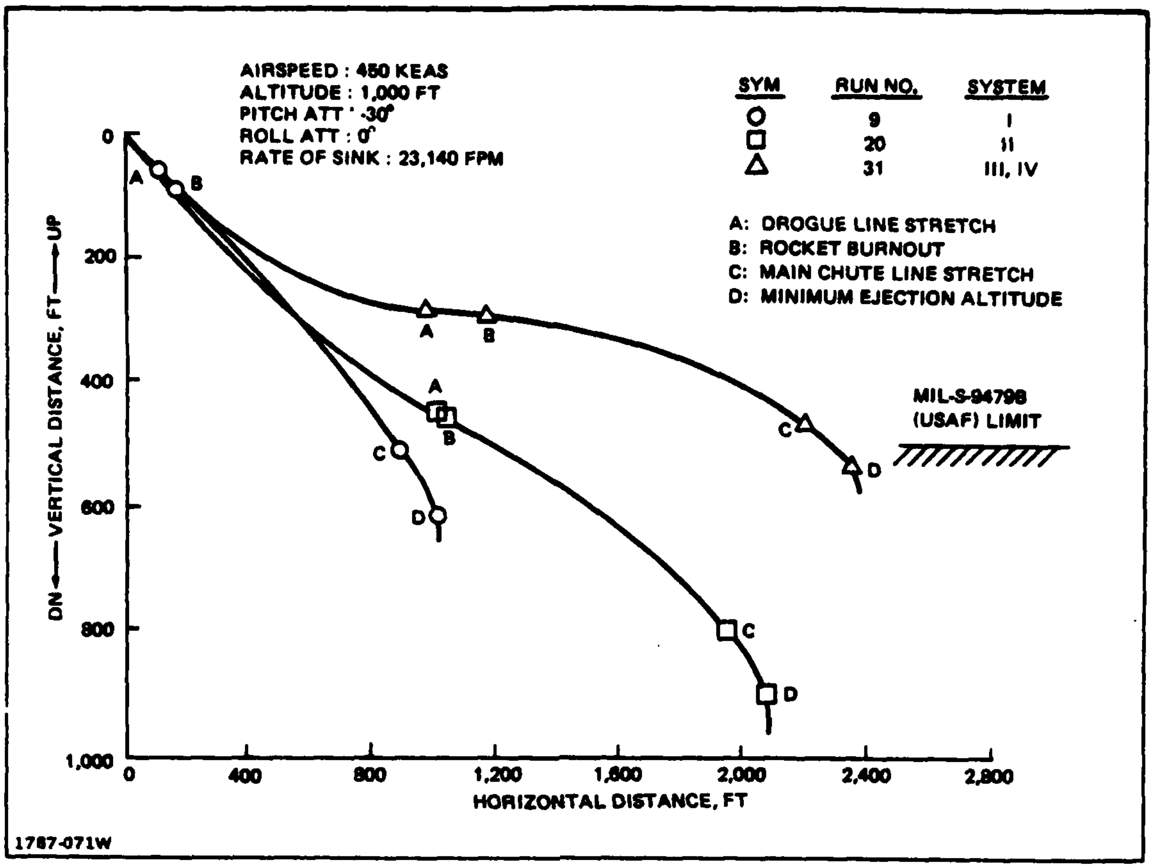


Figure 4-32. Escape Trajectories, Flight Condition 9

limit speed of 250 KEAS. The tolerable spinal (X) and axial (Z) G are -4.8 and 8.6, respectively.

System II: The minimum altitude obtained from the analysis was 902 feet, which exceeds the specification limit. It is doubtful that booster end conditions or optimizing the drogue and main chute inflation times could compensate for the inadequate thrust output from Rocket B.

Systems III & IV: The minimum altitude exceeds the specification value by 34 feet. The addition of a booster plus optimal timing for drogue and main chute releases should qualify the system for this flight condition. The autopilot demonstrated adequate stability and control in the attitude recovery of the system.

Flight Condition 10 (Figure 4-33)

System I: There was no correction to the initial adverse attitudes of 60° roll and 60° pitch down. The system traversed over 500 feet downward before the deployment of the main chute recovered the system. The minimum altitude was 664 feet, exceeding the limit of 550 feet specified in the MIL SPEC. Since the initial speed was low, earlier deployment of the main chute should reduce the minimum altitude. The booster would also contribute to better performance.

System II: Minimum altitude needed for safe ejection is 803 feet. To compensate for the insufficient initial thrust output of Rocket B, the main chute should be deployed sooner for earlier deceleration.

Systems III & IV: Analysis shows that more than adequate performance can be obtained for these two systems. The merit of the higher thrust of Rocket C can

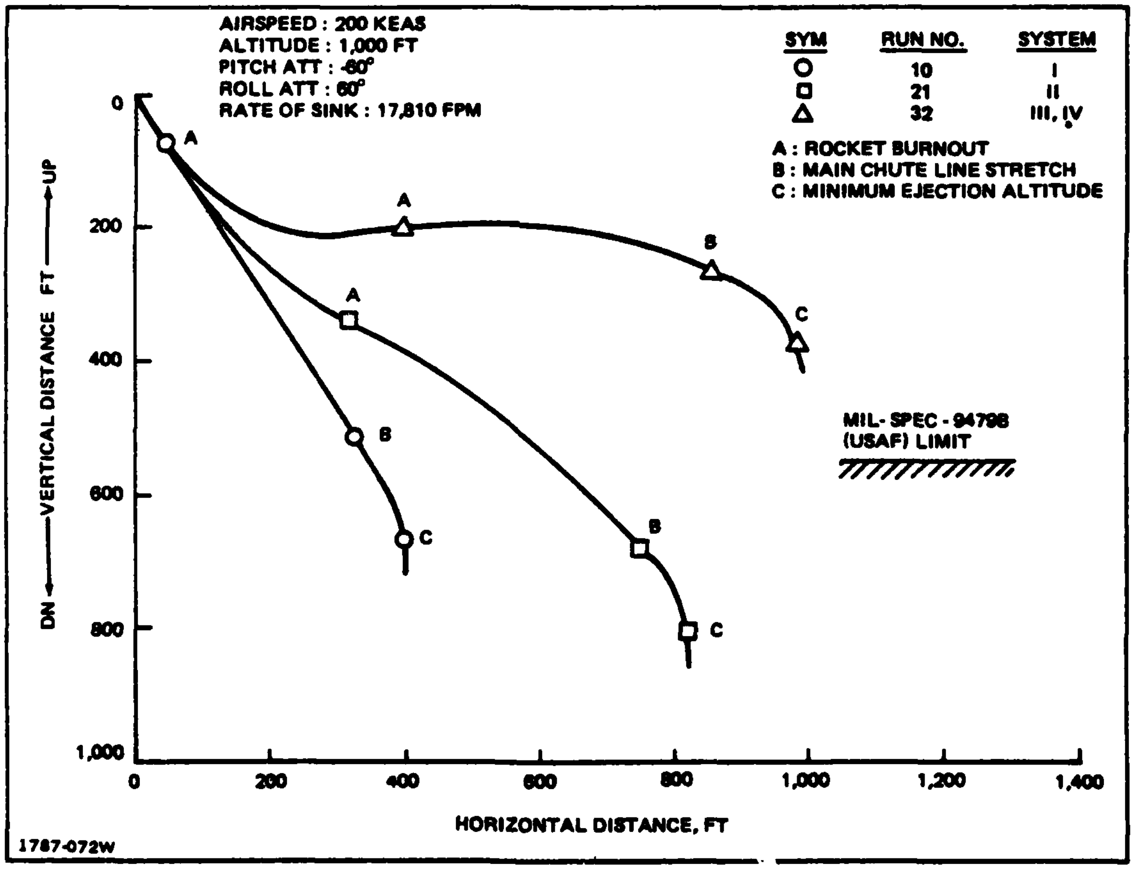


Figure 4-33. Escape Trajectories, Flight Condition 10

be seen from the figure. The plot indicates that with Rocket C these systems were able to recover with small altitude loss. The Vertical Steering mode demonstrated good pitch and roll control of the system. Minimum altitude was 374 feet.

Flight Condition 11 (Figure 4-34)

System I: Minimum altitude was 704 feet, which could be reduced if the main chute was deployed sooner. The G levels are tolerable. As in previous adverse altitude situations, the seat/man traveled in an inverted position until the main chute was fully deployed.

System II: The minimum altitude of 993 feet was 300 feet beyond the MIL SPEC limit. If the timing of the drogue and main chute deployments were

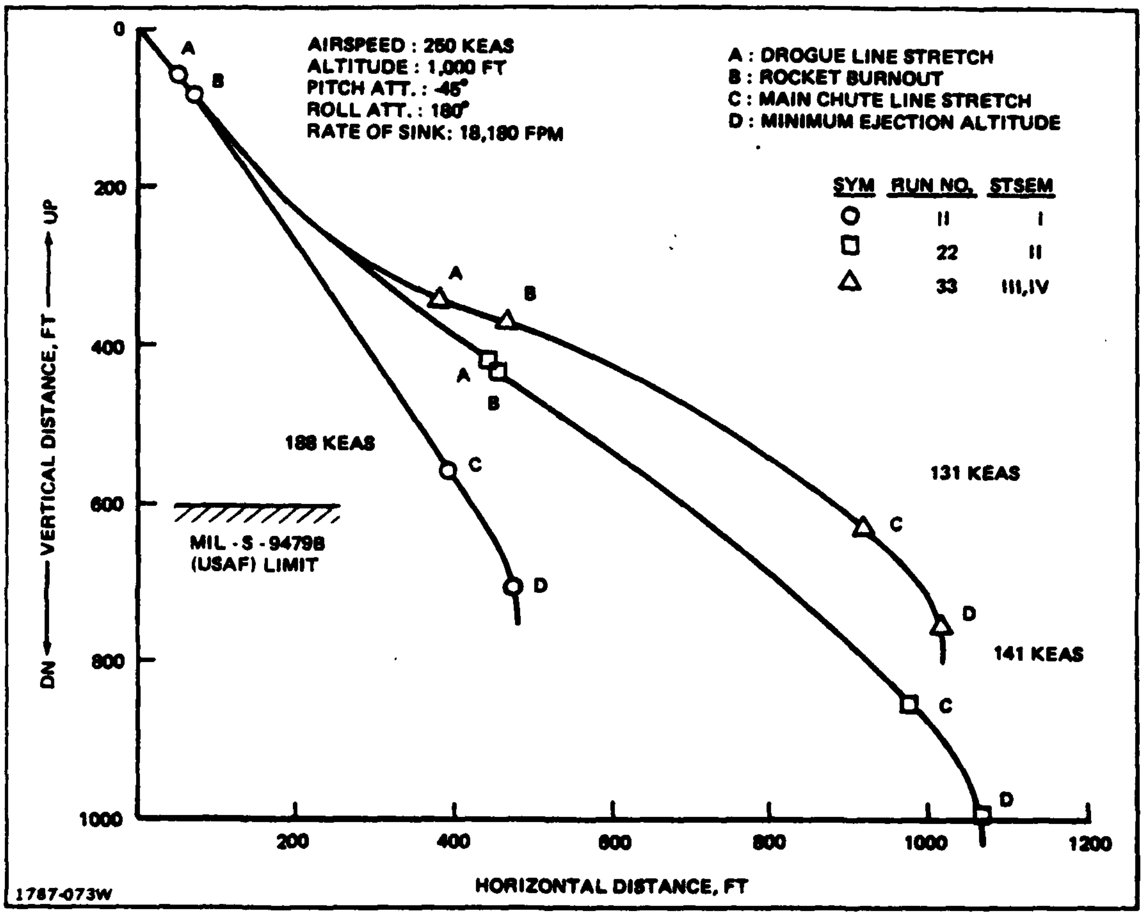


Figure 4-34. Escape Trajectories, Flight Condition 11

optimized, the performance could be improved. It is questionable, however, whether the time adjustments could compensate for the insufficient thrust during the initial stage of the trajectory.

Systems III & IV: The analysis shows that the spec limit was exceeded by 158 feet. However, proper deployment time of the drogue and main chute may reduce the distance to within spec limits.

CONCLUSION: CURVED TRACK

The purpose of this study phase was to analyze Systems I through IV, and select the best system for each of the three speed ranges, namely, 0 to 450 KEAS, 0 to 600 KEAS, and 0 to 687 KEAS. The tabulated results in Table 4-8, in conjunction with the trajectory plots shown in Figures 4-24 to 4-34, were used as a base for choosing the most viable system. The selection was based on the recovery capability, stability, and aircraft clearance of each system; cost and complexity were not considered.

0 to 450 KEAS: System I exhibited adequate performance in the level flight conditions, but performed marginally in some adverse attitude situations, and was inadequate in the most adverse attitude cases. System II performed quite well in this speed regim for level flight, but in the more severe attitude cases failed to meet the MIL-S-9479B limits. Some improvement might be realized for these two systems over this speed range by reducing the main parachute deployment time. Systems III and IV had identical performance in this speed regime, and except for flight condition 11, all spec limits were met. Therefore, on the basis of overall escape performance, System III was the best system of the three candidates for this speed regime.

0 to 600 KEAS: The flight conditions for this speed range were the same as those for the 450 KEAS speed range with one exception at 600 KEAS. System II failed to clear the tail of the aircraft at 600 KEAS. Therefore, System III is also the best system for this speed range.

0 to 687 KEAS: An earlier effort had shown that the only viable system beyond 600 KEAS was System IV, where the Thrust Vector Control feature main-

tains the seat/man in the supine position providing protection from the full impact of the wind blast. Below 600 KEAS, this system was equivalent in performance to System III. Therefore, System IV was the only system that fully satisfied the 0 to 687 KEAS speed range.

4.5.3.2 Tractor Rocket Escape Performance - The tractor rocket system (V) is examined in this study for the performance envelope of 0 to 450 KEAS and 0 to 600 KEAS. The escape trajectories shown in Figure 4-35 through 4-44 were derived from data generated during the sled test program evaluating the application of the Yankee escape system to the EA-6B aircraft (Reference 7).

The system utilizes a 28-foot flat circular main parachute with a three-event, two-stage drogue. Below 250 knots the main canopy is deployed immediately. Above 250 knots the main parachute is deployed after a time delay. The drogue performs in the same manner as in the other systems discussed. All of the escape conditions, except condition 6, are evaluated for the system configuration and escape event schedule shown in Table 4-9.

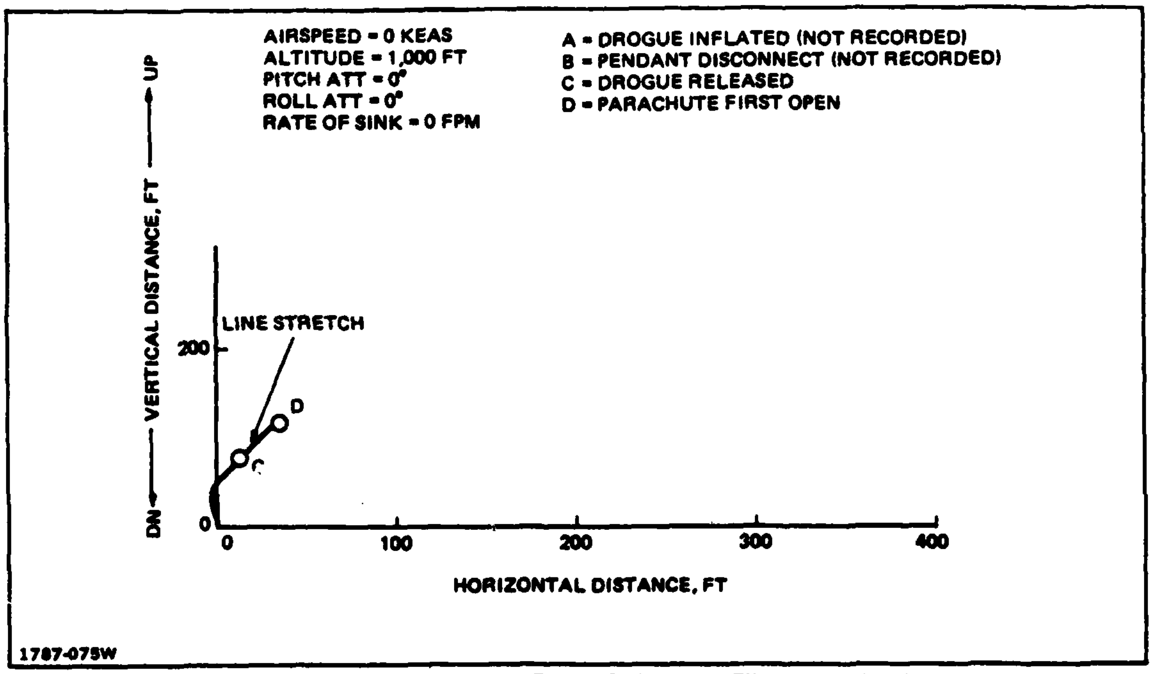


Figure 4-35. Tractor Rocket Escape Trajectories, Flight Condition 1

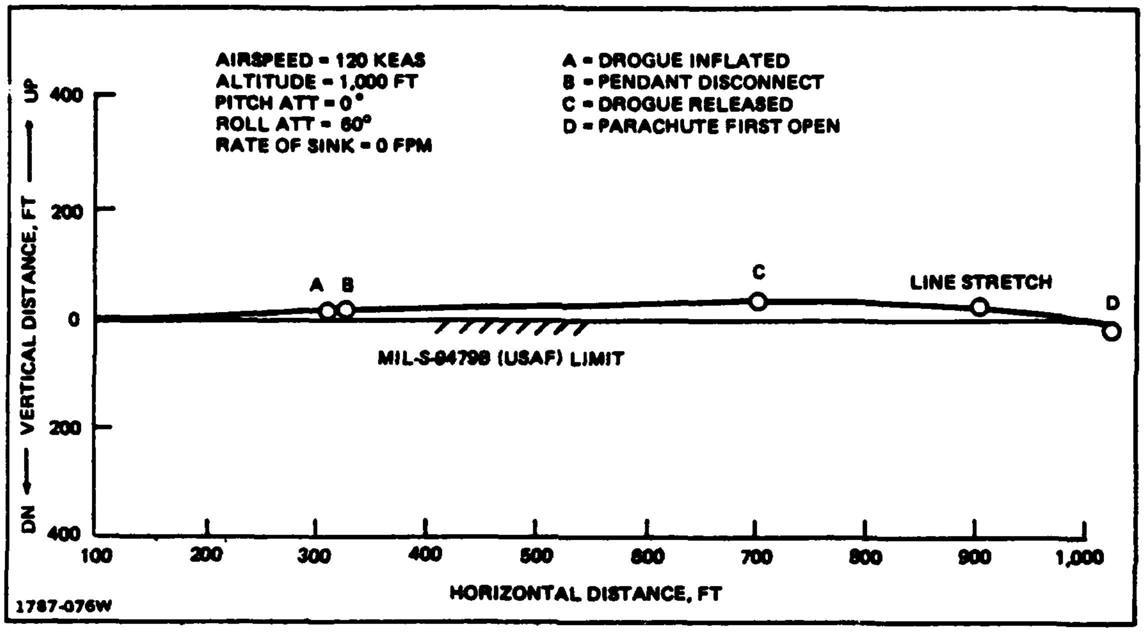


Figure 4-36. Tractor Rocket Escape Trajectories, Flight Condition 2

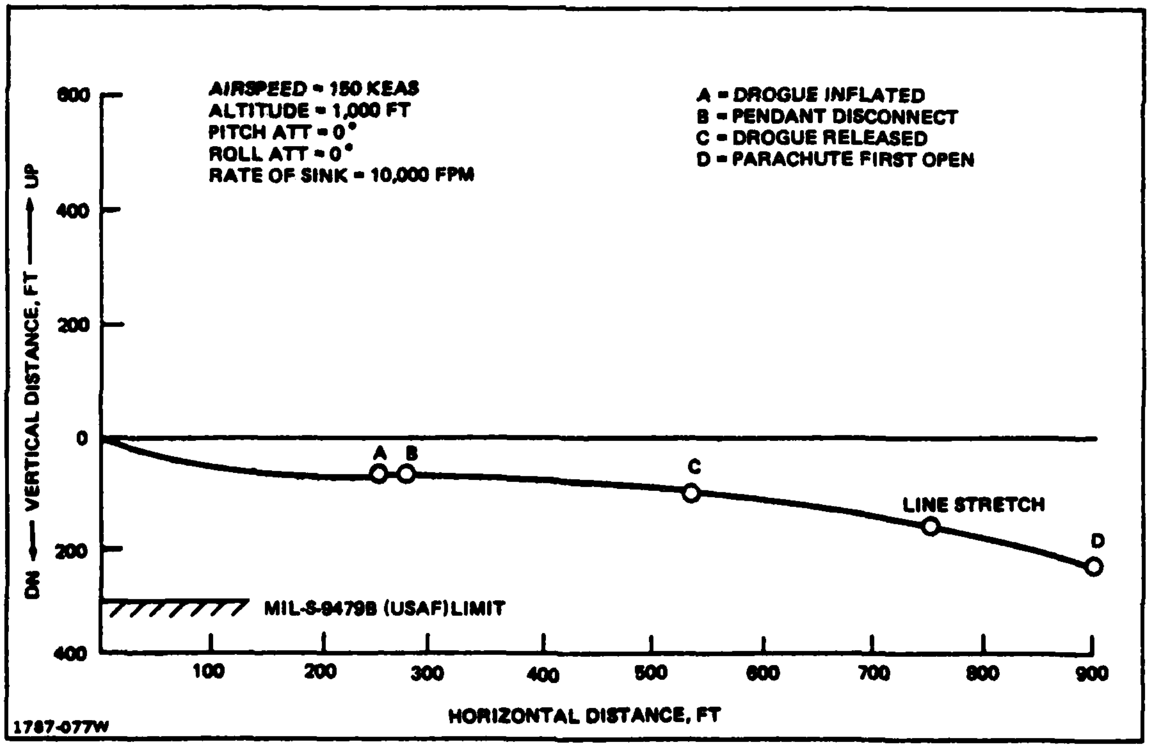


Figure 4-37. Tractor Rocket Escape Trajectories, Flight Condition 3

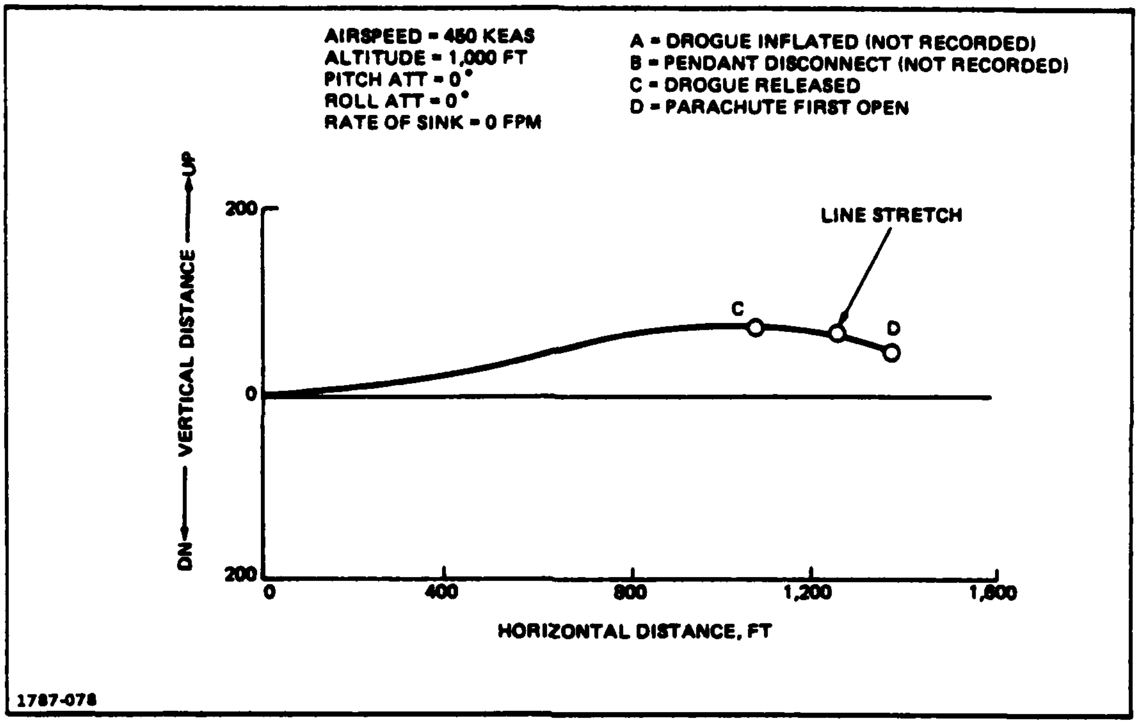


Figure 4-38. Tractor Rocket Escape Trajectories, Flight Condition 4

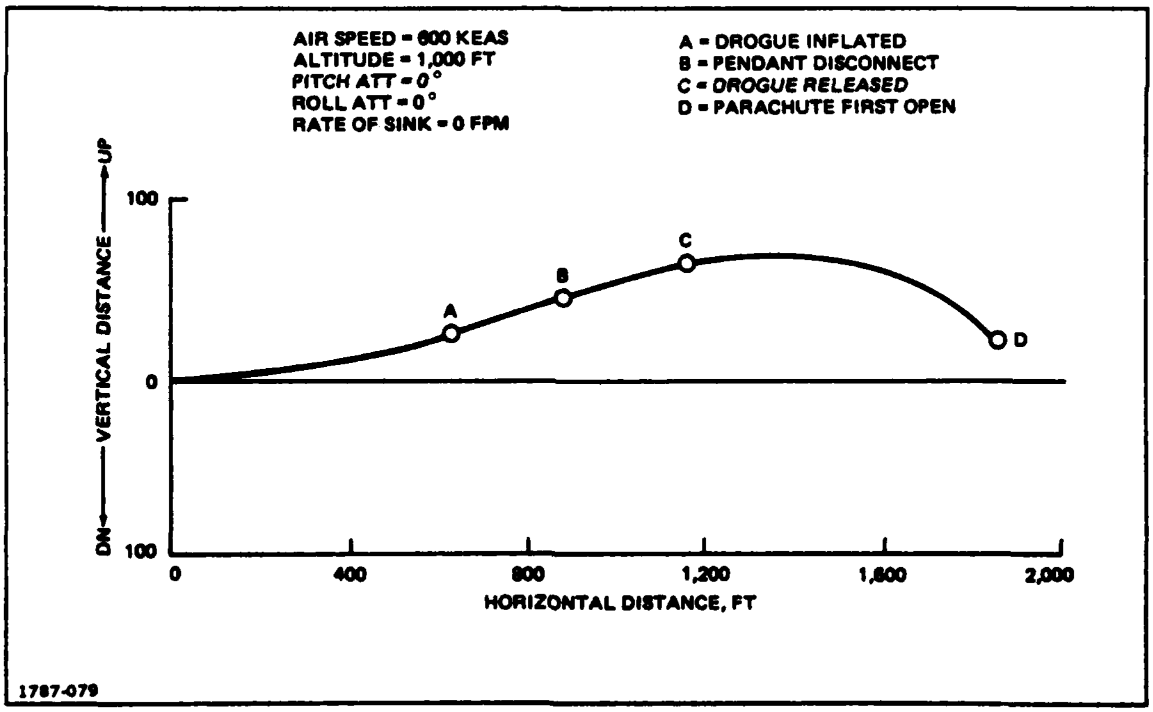


Figure 4-39. Tractor Rocket Escape Trajectories, Flight Condition 5

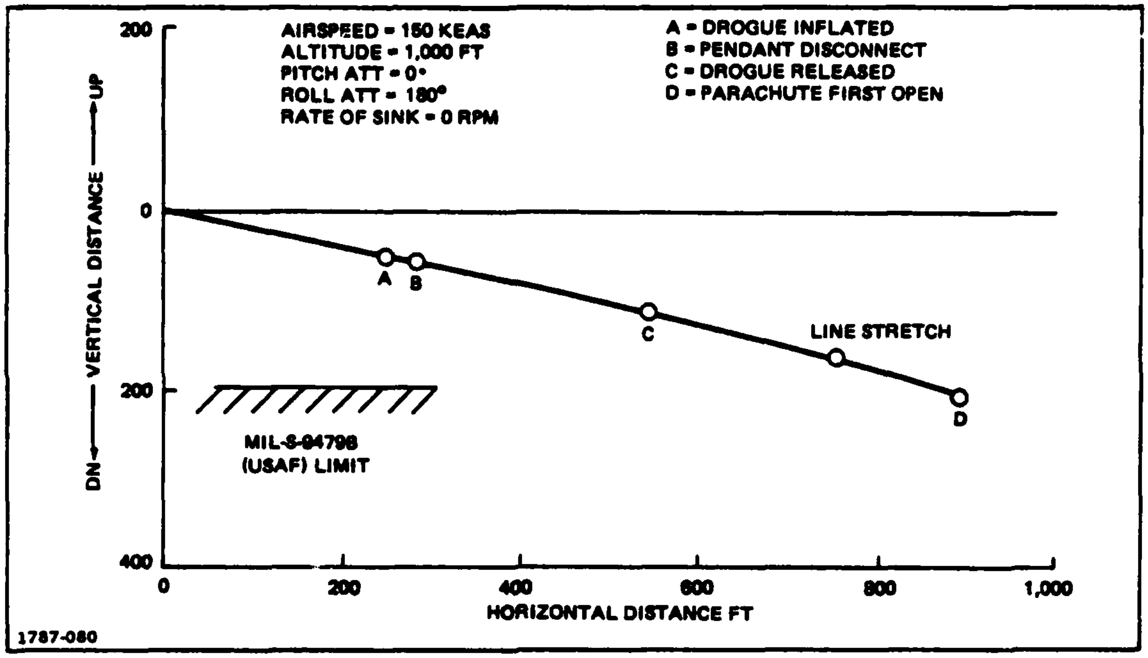


Figure 4-40. Tractor Rocket Escape Trajectories, Flight Condition 7

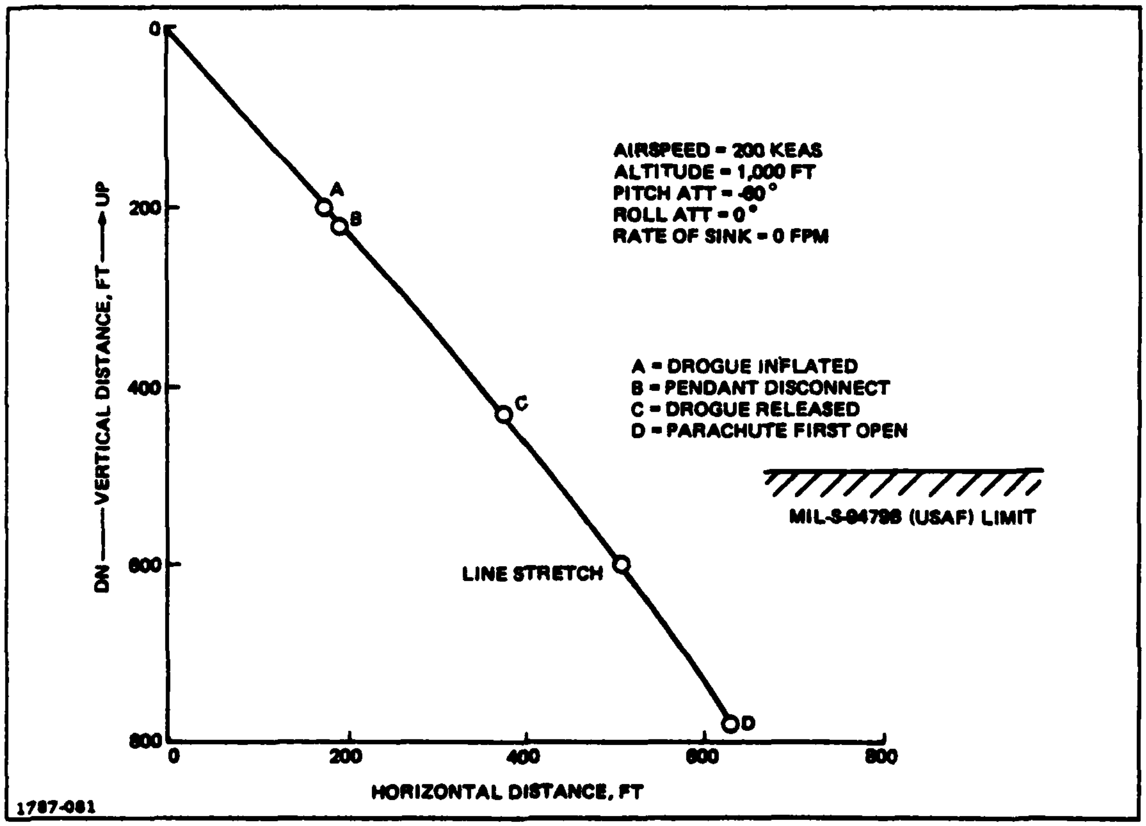


Figure 4-41. Tractor Rocket Escape Trajectories, Flight Condition 8

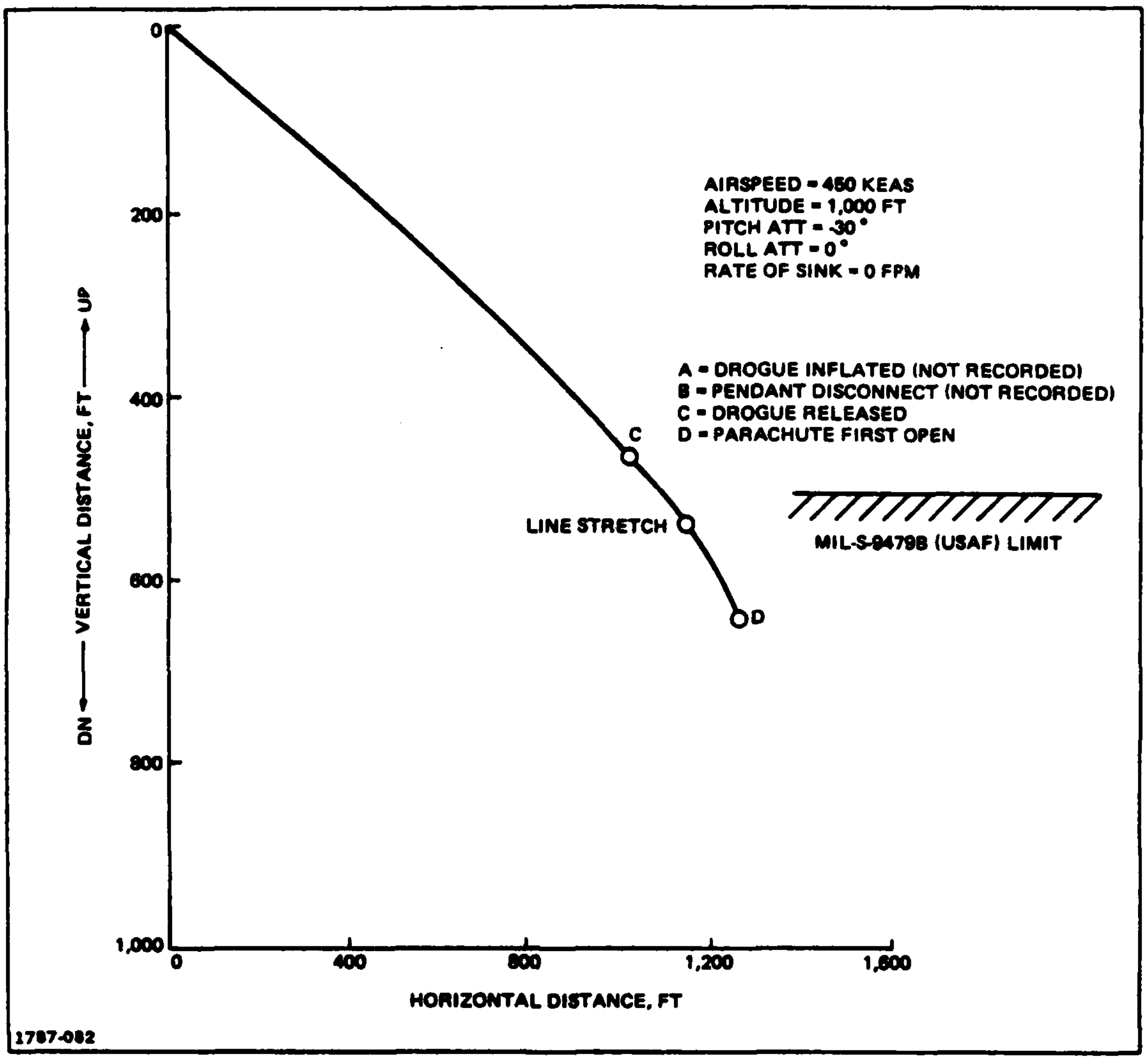


Figure 4-42. Tractor Rocket Escape Trajectories, Flight Condition 9

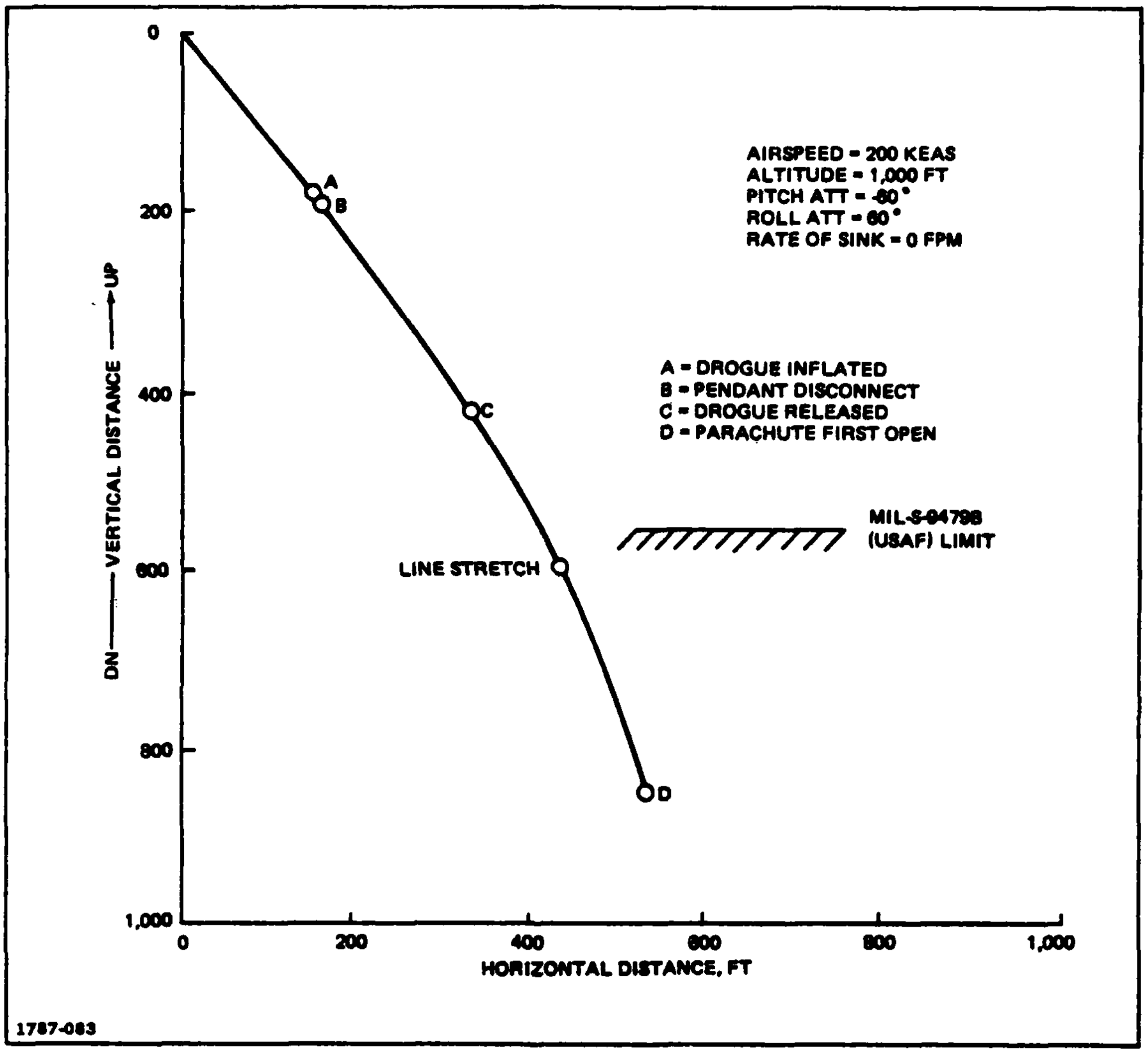


Figure 4-43. Tractor Rocket Escape Trajectories, Flight Condition 10

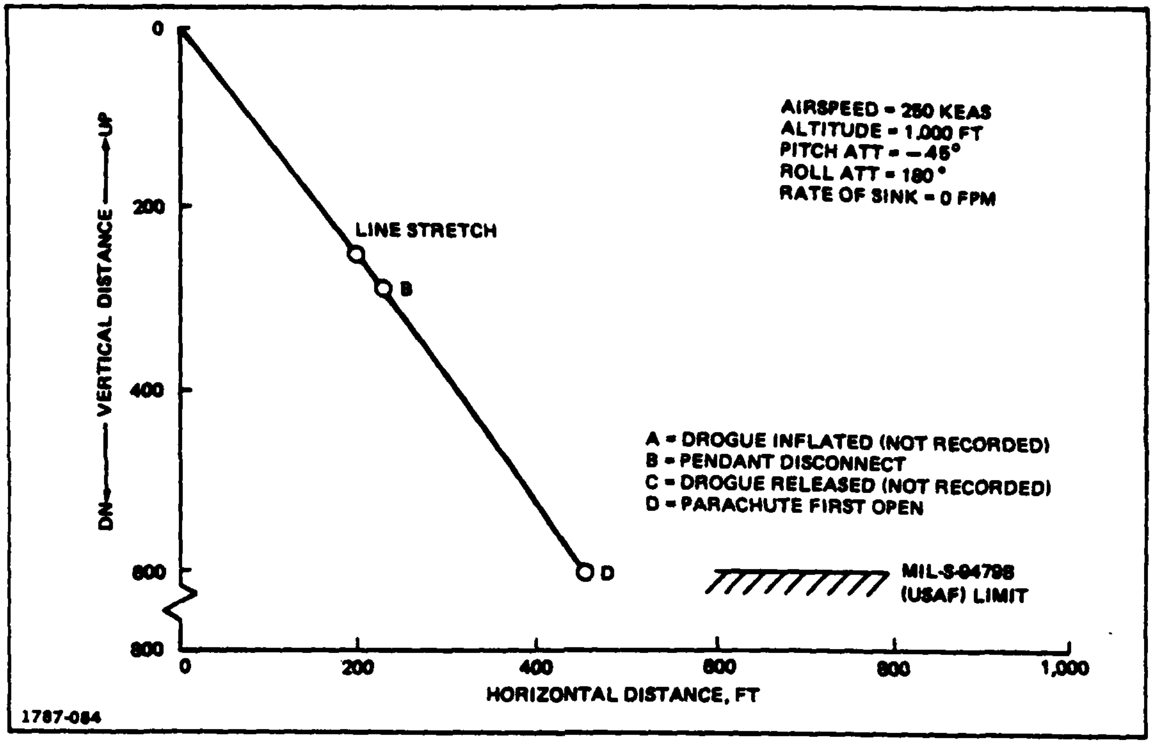


Figure 4-44. Tractor Rocket Escape Trajectories, Flight Condition 11

TABLE 4-9. SYSTEM V CONFIGURATION AND ESCAPE EVENT SCHEDULE

CONFIGURATION	
COMPONENT	**REMARKS**
ROCKET CONTROL SYS	NONE – STANDARD EXTRACTION ROCKET
ROCKET TYPE	2,000-LB THRUST, ½ SEC BURN TIME
DROGUE DIA 1ST STAGE	4 FT
2ND STAGE	1.7 FT
DROGUE BREAK LINK LOAD 1ST TO SECOND STAGE	1000 LB
DROGUE STAGING TIME DELAY 1ST TO 2ND STAGE	1 SEC
MAIN PARACHUTE DIA	28 FT
ESCAPE EVENT SCHEDULE	
EVENT	**ELAPSED TIME (SEC)**
SEAT-A/C SEPARATION	0
DROGUE INITIATION	
(V > 250 KEAS OR ALT > 15,000 FT)	0.25
(ALT < 15,000 FT V < 250 KEAS)	0.25
(ALT < 15,000 FT V > 250 KEAS)	1.3
1787-074W	

CONCLUSION: TRACTOR ROCKET

0 to 450 KEAS

The tractor rocket system performs satisfactorily in the (1) zero speed-zero altitude, (3) low speed, descent with wings level, and (4) wings level at 450 KEAS conditions.

The system shows poor performance in the (8) low speed dive, (9) maximum speed dive, and (10) low speed, 60° bank and dive conditions.

The 30-ft and 40-ft deficiencies in minimum vertical clearance for the adverse attitude conditions 2, 7, and 11 could probably be reduced in a dedicated 0 to 450 KEAS design.

0 to 600 KEAS

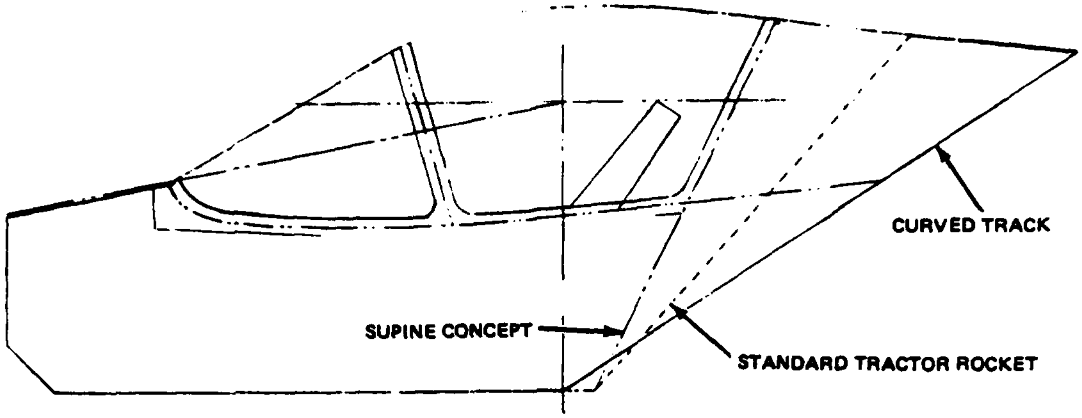
The tractor rocket system performs satisfactorily in the wings level at 600 KEAS condition (5). The conclusions stated for the 0 to 450 KEAS tractor rocket system also apply to the 0 to 600 KEAS system.

4.5.4 Maximum and Intermediate Performance Tradeoff Data

To facilitate the selection of an escape system concept for further development as a preliminary design, tradeoff data were prepared for the two intermediate and the maximum performance preferred concepts. The data is categorized as to impact on the MSLPC , escape system characteristics, and projected development.

The impact of the escape systems on the MSLPC is defined in terms of space required, compromise in cockpit arrangement, and crew station complexity. The space requirement was examined earlier with respect to the maximum performance escape system concepts. Since the values are representative of the baseline intermediate performance concepts, the existing cockpit size data (see Figure 4-45) can be applied to the preferred concept tradeoff.

Aside from the gross effect that the MSLPC has on the conventional aspects of crew station design, the various preferred concepts have little impact on cockpit arrangement from the standpoint of the physical relationships between the pilot, aircraft, escape system, controls, and displays. Each concept, however, does affect aircraft structure and certain subsystems in different ways.



ESCAPE CONCEPT	VOLUME, ft^3	PROFILE AREA, ft^2	SURFACE AREA, ft^2
TRACTOR ROCKET	46.6	20.1	79.2
CURVED TRACK	51.6	22.5	85.4
SUPINE CONCEPT	42.6	17.8	75.8

1787-085W

Figure 4-45. Escape Concept Impact on Cockpit Size

The 450 KEAS Tractor Rocket concept requires a structural support or compartment for the propulsion rocket which is situated aft of the pilot, separate from the seat, and provided with an independent catapult mechanism. A track and roller arrangement provides for an aft movement of the seat to preposition the man for extraction. The same position is used for ingress/egress through selective control of independently powered forward and aft travel.

The 600 KEAS Curved Track concept requires a more elaborate (curved) track/roller arrangement to preposition the sea/man mass for separation. The tracks and associated structural support constrain elbow movement to some extent, but do not prevent access to any control console or panel area.

The 687 KEAS Supine Concept has minimal effect on crew station arrangement, but does impose penalties on the aircraft in terms of weight and complexity resulting from the requirement to jettison the windshield, canopy, and instrument panel prior to ejection.

The evaluation of the escape system concepts for the selection of preferred concepts for each of the 0 to 450, 0 to 600, and 0 to 687 speed ranges was conducted on the basis of data summarized in Table 4-10 (Minimum Vertical Clearance), Table 4-11 (Concept Configuration Tradeoff), and Table 4-12 (Concept Performance Tradeoff).

In review of the escape concept tradeoff, the lowest (best) rating of 62 is recorded by the standard tractor rocket for both the 450 and 600 KEAS systems. A very close second is the supine concept with the vertical steering rocket system, at a rating of 63. The physiological problems of limb flailing that could occur at high speed with the tractor rocket, coupled with the problem of finding the optimum rocket launch angle that gives the best low speed trajectories and adequate tail clearance at high speed, relegates this system to the 0 to 450 KEAS regime. The

TABLE 4-10. MINIMUM VERTICAL CLEARANCE, FT

FLIGHT CONDITION	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS	MIL S 9479B LIMIT
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED CONCEPT	
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS		
1	0	–	791	0	791	0	0	–	791	0	791	0	0	–
2	40	–	55	0	55	0	40	–	55	0	55	0	0	0
3	275	–	325	50	325	50	275	–	325	50	325	50	50	300
4	0	–	69	0	69	0	0	–	69	0	69	0	0	–
5	0	–	66	0	66	0	0	–	66	0	66	0	0	–
6	–	–	–	–	–	–	–	–	–	–	–	–	0	–
7	240	–	256	22	256	22	240	–	256	22	256	22	22	200
8	810	–	634	312	634	312	810	–	634	312	634	312	312	500
9	670	–	613	534	613	534	670	–	613	534	613	534	534	500
10	880	–	664	374	664	374	880	–	664	374	664	374	374	550
11	630	–	704	758	704	758	630	–	704	758	704	758	758	600

NOTES: STD = STANDARD; FR = FIXED ROCKET; VS = VERTICAL STEERING.
MIN ALT ON TRACTOR GRAPHS (SYSTEM V) DEPICTS MAIN PARACHUTE OPENING. ABOVE CHART ADDS 30 FT ALT FOR STEADY-STATE (30 F.P.S. TOTAL/ 24 F.P.S. VERTICAL) CONDITION.

1787-066W

TABLE 4-11. ESCAPE CONCEPTS CONFIGURATION TRADEOFF

	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	CONCEPT
AIRCRAFT HARDWARE COMPLEXITY													
AIRCRAFT CANOPY	1	1	1	1	1	1	1	1	1	1	1	1	1
INSTRUMENT PANEL	1	1	1	1	3	3	1	1	1	1	3	3	3
BOOST/PREPOSITIONING	2	2	2	2	1	1	2	2	2	2	1	1	1
SEAT/ACFT INTERFACE STRUCTURE	2	2	2	2	1	1	2	2	2	2	1	1	1
CANOPY THRUSTERS	1	1	1	1	3	3	1	1	1	1	3	3	3
COCKPIT SIZE	2	3	3	3	1	1	2	3	3	3	1	1	1
WINDSHIELD JETTISON	–	–	–	–	3	3	–	–	–	–	3	3	3
INSTRUMENT PANEL JETTISON	–	–	–	–	3	3	–	–	–	–	3	3	3
SUBTOTAL	9	10	10	10	16	16	9	10	10	10	16	16	16
ESCAPE-SYS HARDWARE COMPLEXITY													
PROTECTIVE BUCKET	1	1	1	1	1	1	1	1	1	1	1	1	1
DROGUE/STABILIZER	2	2	2	2	2	2	2	2	2	2	2	2	2
ROCKET/THRUST VECTORING	1	4	1	4	1	4	1	4	1	4	1	4	4
RESTRAINT	1	1	2	3	2	3	1	1	2	3	2	3	3
SEAT POSITIONING/SEPARATION	1	1	3	3	–	–	1	1	3	3	–	–	–
TRACKS	2	2	3	3	2	2	2	2	3	3	2	2	2
SEAT ASSEMBLY	2	2	2	2	2	2	2	2	2	2	2	2	2
SUBTOTAL	10	13	14	18	10	14	10	13	14	18	10	14	14
SIZE/COST/RISK—PENALTIES													
WEIGHT (ACFT/ESC SYS)	1	3	2	3	2	3	1	3	2	3	2	3	3
SIZE (COCKPIT VOLUME)	2	3	3	3	1	1	2	3	3	3	1	1	1
COST (Δ/UNIT)	1	2	1	2	2	3	1	2	1	2	2	3	3
RELIABILITY RISK	3	3	1	3	1	2	3	3	1	3	1	2	2
MAINTAINABILITY RISK	2	2	1	2	1	2	2	2	1	2	1	2	2
DEVELOPMENT RISK	2	2	1	2	1	2	2	2	1	2	1	2	2
SUBTOTAL	11	15	9	15	8	13	11	15	9	15	8	13	13
TOTAL	30	38	33	43	34	43	30	38	33	43	34	43	43

NOTES: STD = STANDARD; FR = FIXED ROCKET; VS = VERTICAL STEERING.
RATING, 1 = LOW; 2 = MODERATE; 3 = HIGH; 4 = EXTREME.

1787-087W

TABLE 4-12. ESCAPE CONCEPT PERFORMANCE TRADEOFF

	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	CONCEPT
DIVE	4	2	3	1	3	1	4	2	3	1	3	1	1
SINK RATE	2	2	3	1	3	1	2	2	3	1	3	1	1
ROLL	2	2	3	1	3	1	2	2	3	1	3	1	1
ADVERSE ATTITUDE	3	2	3	1	3	1	3	2	3	1	3	1	1
SPIN	2	2	2	2	2	2	2	2	2	2	2	2	2
TAIL CLEARANCE	2	2	2	2	2	1	2	2	2	2	2	1	1
BODY ACCELERATIONS	3	3	2	2	2	2	3	3	2	2	2	2	2
COCKPIT CLEARANCE	1	1	2	2	1	1	1	1	2	2	1	1	1
TIMING (COCKPIT CLEARANCE)	2	2	2	2	1	1	2	2	2	2	1	1	1
STABILIZATION	2	2	4	1	4	1	2	2	4	1	4	1	1
HIGH SPEED	3	3	3	2	3	2	3	3	3	2	3	2	2
HIGH ALTITUDE	2	2	2	2	2	2	2	2	2	2	2	2	2
HIGH "G" ON AIRCRAFT	2	2	3	3	3	3	2	2	3	3	3	3	3
LOW ALT/ADVERSE ATT	2	2	4	1	4	1	2	2	4	1	4	1	1
SUBTOTAL	32	29	38	23	36	20	32	29	38	23	36	20	20
TRADEOFF SUMMARY													
CONFIGURATION	30	38	33	43	34	43	30	38	33	43	34	43	43
PERFORMANCE	32	29	38	23	36	20	32	29	38	23	36	20	20
TOTAL	62	67	71	66	70	63	62	67	71	66	70	63	63

NOTES: STD = STANDARD; FR = FIXED ROCKET; VS = VERTICAL STEERING.
RATING, 1 = EXCELLENT; 2 = GOOD; 3 = FAIR; 4 = POOR.

1787-088W

supine concept affords more capability regarding limb restraint and utilizes a high impulse long burning rocket that gives sufficient tail clearance at high speeds. In summation, the vertical steering or the vector control supine (System IV) concept was the choice in the earlier 0 to 687 KEAS evaluation. The vertical steering supine (System III) concept is chosen as the 0 to 600 KEAS system. The tractor rocket (System V) concept is selected as the 0 to 450 KEAS system.

4.5.5 Preferred Concept Selection

The selection of one of the three preferred concepts was necessary to develop further as a preliminary design. The systems recommended as preferred concepts for the intermediate and maximum performance envelopes are described as follows:

- System V (Zero to 450 KEAS) - The system utilizes a 0.50-second extraction rocket that has a peak thrust of 2000 pounds. Drogues are not deployed below 250 KEAS. The data shown in Table 4-13 were prepared to assist in the selection of a preliminary design concept.
- System III (Zero to 600 KEAS) - The system utilizes a 2.00-second, upward-seeking rocket that has a peak thrust of 5000 pounds. Drogues are not deployed below 250 KEAS
- System IV (Zero to 687 KEAS) - The system utilizes a 2.00-second, upward-seeking rocket that has a peak thrust of 5000 pounds. From 600 to 687 KEAS the upward-seeking circuit is turned off and the rocket performs a vector control function only. Drogues are not deployed below 250 KEAS.

4.6 PRELIMINARY DESIGN

The Supine Concept (System IV) was selected as the preferred concept for development as a preliminary design (Subsection 4.6.2). A review of the aerodynamic performance capability, in conjunction with the preliminary design effort, was considered necessary to establish the final system configuration. The review includes a reexamination of the 11 flight conditions as well as time histories of angular seat motion and body axis G on the crewman throughout the ejection.

TABLE 4-13. PREFERRED CONCEPT SELECTION TRADEOFF DATA

	450 KEAS	600 KEAS	687 KEAS
	SYSTEM V TRACTOR	SYSTEM III SUPINE VSC	SYSTEM IV SUPINE VSC/TYC
1. IMPACT OF CONCEPT ON MSLPC			
COCKPIT VOLUME (FT^3)	51.6	42.6	42.6
COCKPIT ARRANGEMENT	MINIMAL	NONE	NONE
COMPLEXITY	LOW	MODERATE	MODERATE
2. SYSTEM CHARACTERISTICS			
PERFORMANCE			
STABILITY (+/-)	INHERENT	*	TVC
SUSTAINED $+G_z$ (UNIT)	16	11.3**	11.3
HIGH ALT	GOOD	GOOD	GOOD
LOW ALT	GOOD	EXCEL	EXCEL
ADVERSE ATTITUDE (MIN DIST)	GOOD	EXCEL	EXCEL
WEIGHT (EJECTED) (LB)	494	521	521
COMPLEXITY			
NO. OF MODES	4	4	4
NO. OF SENSORS	1	1	2
NO. OF INITIATORS	5	4	4
COST (SYS $)	BASE (42,000)	+36525	+40375
3. PROJECTED DEVELOPMENT			
DEVELOPMENT (YEARS)	2	4	4
COST ($)	27M	48M	63M
RISK (HI/LO)	MODERATE	MODERATE	MODERATE

*450 AND 600 KEAS EVALUATIONS WERE CONDUCTED WITH THE THRUST VECTOR THROUGH THE C.G. OF 95 PERCENTILE CREWMAN. FURTHER STABILITY ANALYSIS OF ENTIRE PILOT POPULATION IS NECESSARY.

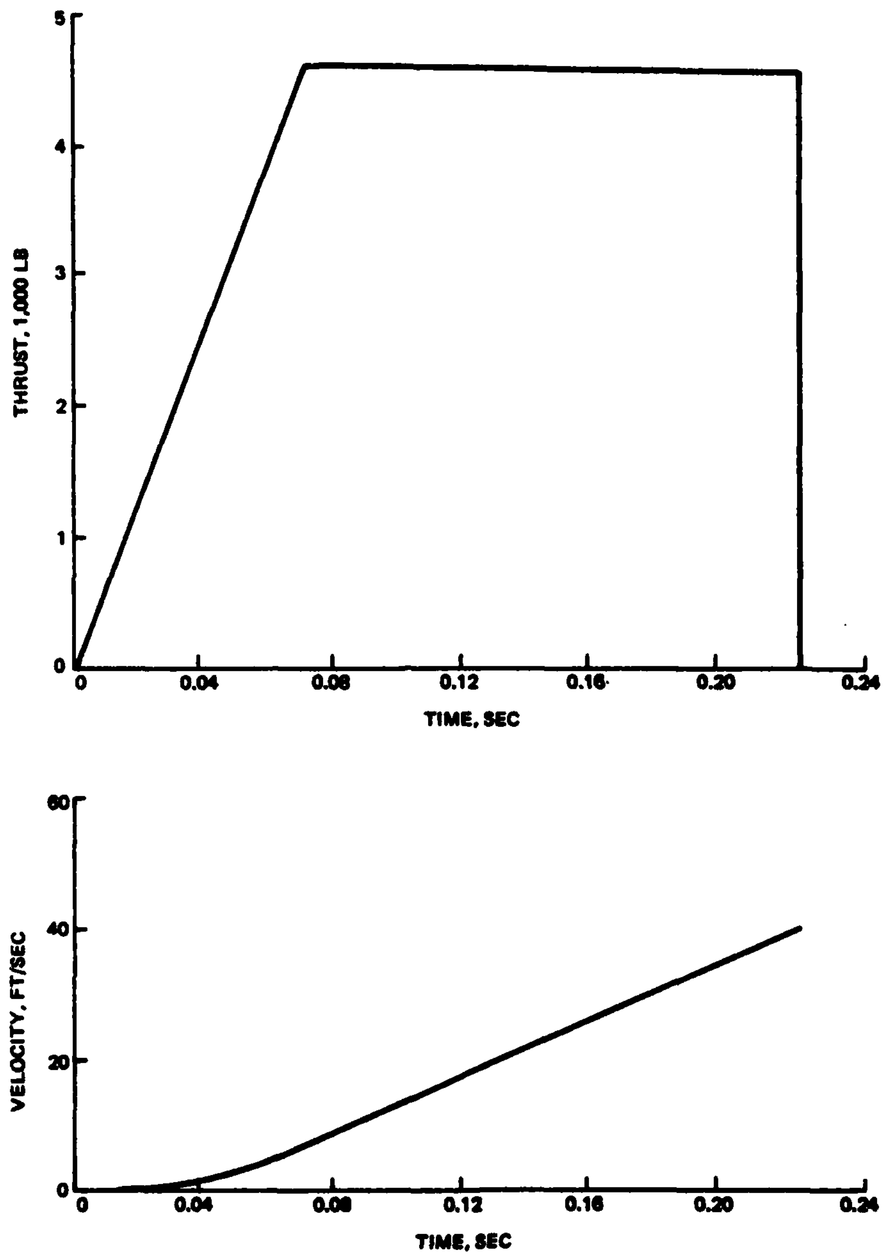
**PROJECTED ON BASIS OF OPTIMIZED BOOST, ROCKET IGNITION, THRUST, AND PENDANT LENGTH.

1787-089W

Seat Booster

The boost system designed for the supine seat is gas-operated and utilizes one 10-inch telescoping catapult, to effect a satisfactory ejection of the seat from the aircraft. The seat translates upward and rotates about the two upper-aft adjustment rollers. At the end of the stroke, the seat is released from the aircraft and is in free flight, propelled at that point by the rocket which is attached to the seat. As the seat enters the airstream, it possesses an upward velocity relative to the aircraft and an aft pitch rate as a result of forces applied to the seat by the boost system. The primary function of a seat boost system is to produce a clean separation between the seat and its parent aircraft under the most severe ejection conditions. It should be noted that this study did not consider the effects of aircraft acceleration on the boost system performance. It is also advantageous to boost the seat to its exit position in the shortest possible time, since the longer the seat remains with the aircraft the more hazardous the ejection. It is evident that the higher the exit velocity of the seat, the cleaner the separation will be and the least amount of time will be spent with the aircraft. Therefore, it was important to determine how high a velocity the supine seat could tolerate. For conventional upright escape seats, the exit velocity is restricted to preclude injuries to the spine due to the boost force applied to the seat. However, this is not the case for the supine seat since the crewman can accept many more G axially than he can through his spine. It was thought initially that higher exit velocities could result in more altitude required for adverse attitude ejections. However, a study made by varying the exit velocities for adverse attitude ejections showed that the required altitude was relatively insensitive to the exit velocities. It became evident that the maximum exit velocity would be restricted only by the design of the boost system. At this point in the investigation the boost mechanism had not been completely defined, and it was necessary to select a nominal system to complete the trajectory analysis. A 40-foot-per-second exit velocity was chosen which corresponded closely with conventional boost systems. These boost characteristics are presented in Figure 4-46 and were utilized for this study.

It should be noted that at the completion of the final boost system design, the end velocity was estimated to be 20 feet per second. These results will not alter any of the conclusions reached with the 40-foot-per-second booster.



1787-090W

Figure 4-46. Seat Booster Characteristics

As noted previously, the seat in its travel to the exit position is rotated to a horizontal attitude. At the exit position the seat possesses a positive pitch rate of approximately 500° per second. For ejections at high speed flight conditions, this positive pitch rate results in a favorable design feature, since the aerodynamic moment on the seat as it enters the airstream tends to pitch the seat negatively. The rocket control system will counter this moment so that the seat maintains a horizontal attitude for wind blast protection. Therefore, the positive pitch rate resulting from the boost system will assist the rocket in maintaining a favorable attitude. However, since the computer analyses were performed prior to the completion of the final boost system design, this beneficial effect was not included in the simulations.

Rocket Propulsion Characteristics

The primary functions of the rocket propulsion system are to provide the force necessary to propel the seat clear of all aircraft structure and to provide the force required for in-flight attitude control for ejections throughout the escape envelope. The basic character of the thrust time history was developed during the performance evaluation presented in Subsection 4.4. This analysis was limited to the high speed environment where pitch plane trajectories were calculated and seat booster characteristics were not included. Under these assumptions the criterion utilized to evaluate the thrust characteristics was seat tail clearance. To meet this criterion, a 5000-pound peak thrust with a relatively fast onset rate was required. A thrust duration of 2 seconds was used for this phase in anticipation of ejections at adverse attitude and dive conditions. During the intermediate performance envelope evaluation, presented in Subsection 4.5, ejections at adverse attitudes and dive conditions were studied more closely. The 2-second duration requirement was verified during this investigation and the fast onset rate required for tail clearance at high speed was also beneficial for improving the seat performance under adverse attitude and dive conditions. The preliminary design phase, presented in this subsection, investigates ejections of the supine seat throughout the maximum performance envelope with all the subsystems operating. It was found that the seat boost system reduced the reliance on the rocket thrust for tail clearance at high speed; however, beneficial effects on seat performance under adverse

attitude and dive conditions were not altered when the seat boost system was included. The rocket thrust characteristics were, therefore, retained for the preliminary design phase and are presented as a function of time in Figure 4-47.

Rocket Control System

The supine seat rocket system contains a blended autopilot consisting of a vertical steering control system (VSC) which is activated below 600 KEAS and a thrust vector control system (TVC) which is activated above 600 KEAS.

The purpose of the VSC system is to select a vertical-up ejection trajectory for an escape seat, irrespective of aircraft attitude at initiation of ejection. This system will adequately compensate for CG variations corresponding to the pilot population and for rotational rates generated by the seat booster. The benefits of employing the VSC system has been demonstrated dramatically in Subsection 4.5 of this report where the minimum altitude requirements for adverse attitude and dive conditions have been substantially reduced compared to a conventional fixed rocket system.

The purpose of the TVC system is to provide the necessary wind blast protection by maintaining the attitude existing at the cockpit exit position at the time of ejection. The wind blast protection is provided by carefully positioning the seat with its back horizontal to the airstream along its flight trajectory. This protection is required at speeds above approximately 600 KEAS. This speed was a nominal figure representative of the upper limit of most conventional seats.

It should be noted that the two control systems, TVC and VSC, are diametrically opposed under certain flight conditions and identical under others. For example, if an ejection takes place while the aircraft is inverted the TVC system would maintain the seat in the inverted attitude allowing the rocket thrust to drive the seat and crewman toward the ground. If the VSC system were called under these same conditions the autopilot would respond by rolling the seat upright which would direct the thrust vector in a vertical upward direction. If an ejection occurred while the aircraft was in a wings level attitude, both the TVC and VSC systems would respond identically by maintaining the level attitude. It is obvious that neither system alone can satisfy all the requirements. If the TVC system were

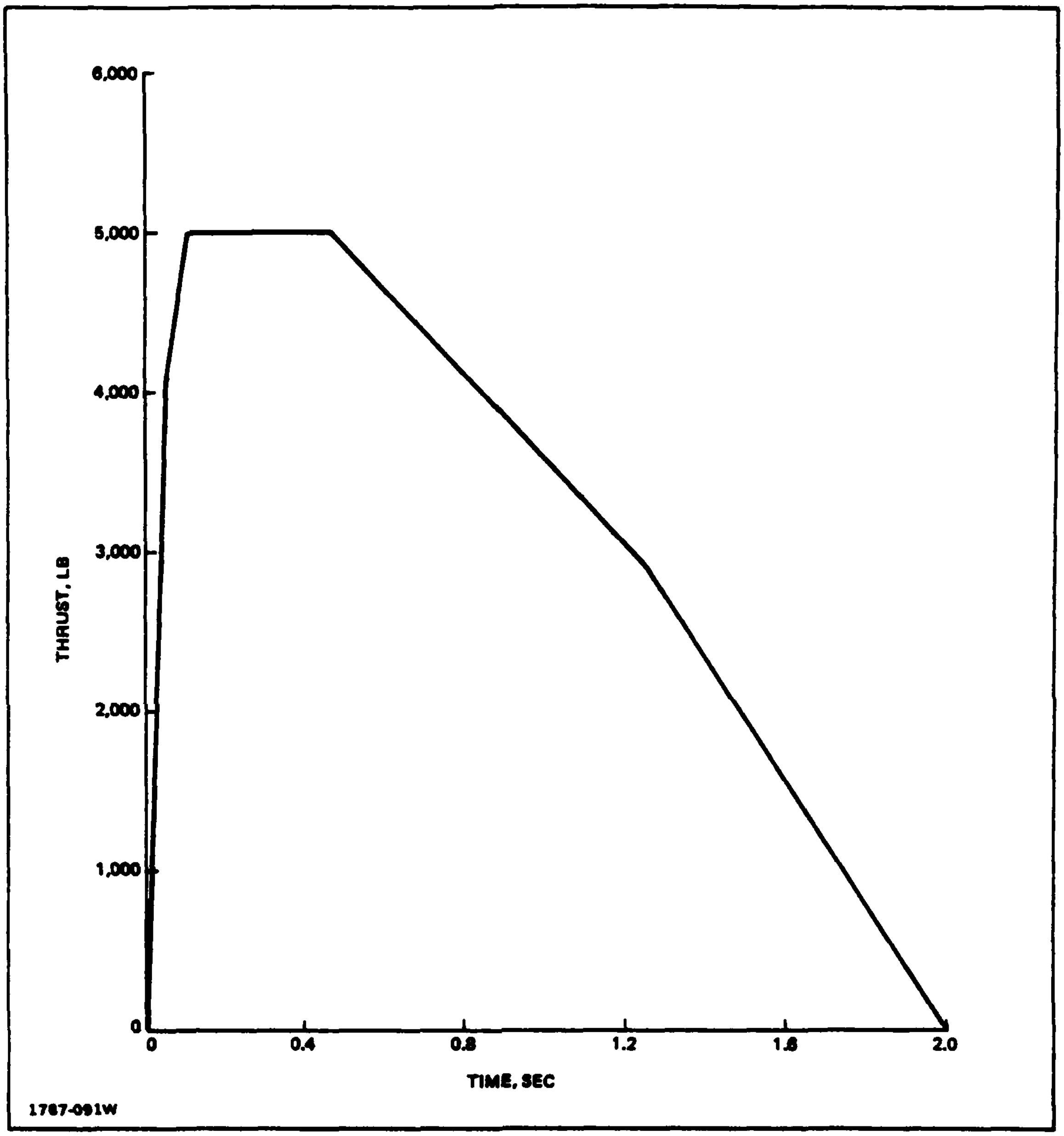


Figure 4-47. Rocket Thrust Time History

utilized throughout the speed regime, ejections under adverse attitude and dive conditions would be severely limited. If the VSC system were utilized, the crewman would not have adequate wind blast protection under all conditions in the high speed environment making ejections above 600 KEAS hazardous. It is for these reasons that the blended system of TVC above 600 KEAS and VSC below 600 KEAS was proposed.

Drogue Parachute System

The supine seat utilizes a single 2-foot diameter hemisflow drogue which is deployed 1.505 seconds from the end of the boost stroke for all ejections irrespective of flight condition. The drogue is utilized at all speeds to provide continuous attitude control between rocket burnout and main chute deployment. During the early phases of the program a two-stage system was contemplated for the supine seat similar to those utilized in conventional upright ejection seats. The first stage being a large chute which assures attitude stabilization at low speeds and collapses to a smaller second stage drogue (approximately 2 foot diameter) at high speeds. It became evident that the larger first stage drogue was not required for the supine seat primarily because of the rocket control system which alleviates any large displacements and rates of the seat prior to drogue deployment. This is not true of the conventional seat which depends completely on the drogue system to control the seat following the fixed rocket thrusting. The 2-foot diameter canopy was selected during the performance evaluation phase presented in Subsection 4.4. This size drogue was found large enough to provide sufficient attitude control at high speed between rocket burnout and main chute deployment with minimum deceleration. During the preliminary design phase presented in this subsection, the 2-foot canopy drogue has demonstrated similar control prowess for the low speed adverse attitude flight conditions. The 2-foot diameter drogue was not evaluated in terms of its capability to stabilize the seat/man combination during descent from high altitude (above 15,000 feet) following a high altitude ejection.

Main Parachute System

The main chute system utilizes a conventional 28-foot flat circular parachute. At a specified time (3.35 seconds) after the seat reaches the end of the catapult stroke, the drogue chute deploys the main chute from its pack. This time was established so that parachute line stretch would occur below 250

KEAS for the high speed ejection (687 KEAS, sea level). This timing guarantees that the main chute openings for all flight conditions will occur at speeds less than 250 KEAS and the parachute will remain intact.

4.6.1 Supine Seat Performance

The supine seat performance was evaluated by calculating trajectories and time histories for each of the 11 flight conditions analyzed in Subsection 4.4. These calculations differ from the previous ones in that the seat catapult characteristics were included in the total escape sequence. The results presented here represent a preliminary design effort of the total system. (A listing of these escape conditions can be found in Table 4-6.) Tables 4-14 presents an event schedule associated with a supine seat ejection. A lettered symbol is assigned to each event in this schedule and the corresponding symbols can be found on each trajectory plot, thereby locating the seat spatially at the event time. It should be noted that time zero is shown to occur at seat boost initiation which represents escape initiation as far as the computer calculation is concerned. In reality, escape initiation occurs 0.4 seconds prior to that, at which time the canopy is jettisoned.

The performance results are presented in the form of spatial plots and time histories. For each ejection a trajectory is presented in the pitch plane and in the lateral plane where applicable. In addition, time histories are

TABLE 4-14. EVENT SCHEDULE, SUPINE CONCEPT EJECTION

SYMBOL	EVENT	TIME, SEC
A	ESCAPE INITIATION SEAT BOOST INITIATION	0
B	END OF STROKE ROCKET THRUST INITIATION	0.22
C	DROGUE DEPLOYMENT	1.725
D	DROGUE LINE STRETCH	1.81
E	ROCKET BURNOUT	2.22
F	MAIN CHUTE DEPLOYMENT MAN/SEAT SEPARATION	3.57
G	MAIN CHUTE LINE STRETCH	4.82
H	TERMINAL SPEED	–
1787-093W		

plotted for the seats' angular displacements in pitch, roll, and yaw (Figure 4-48), as well as the crewman's body G (spinal, axial, and lateral). The following is a discussion of the results of each of the 11 flight conditions, calculated for the supine seat.

Flight Condition 1 - The results of the zero-zero ejection are shown in Figure 4-49. The trajectory reaches an apogee of 1230 feet, at which height the crewman has no difficulty in descending safely to the ground. The pitch attitude of the seat is maintained at zero degrees (back horizontal to ground) by virtue of the vertical steering rocket for the first two seconds of the trajectory. As the rocket burns out, the drogue chute is deployed and aligns the seat with the velocity vector (approximately 90°). The next event to occur is the man/seat separation and main chute deployment. This is followed by parachute line stretch at approximately 4.8 seconds, at which time the crewman begins his rotation through the apogee of the trajectory and back down to the ground. Throughout the entire trajectory the attitude of the supine seat is fully controlled, first by the seat rocket and then by the drogue chute. Finally, the time history of the G on the crewman shows a peak of 10 G in the axial direction produced by the rocket force, and negative 3.6 G along the spine from the main parachute.

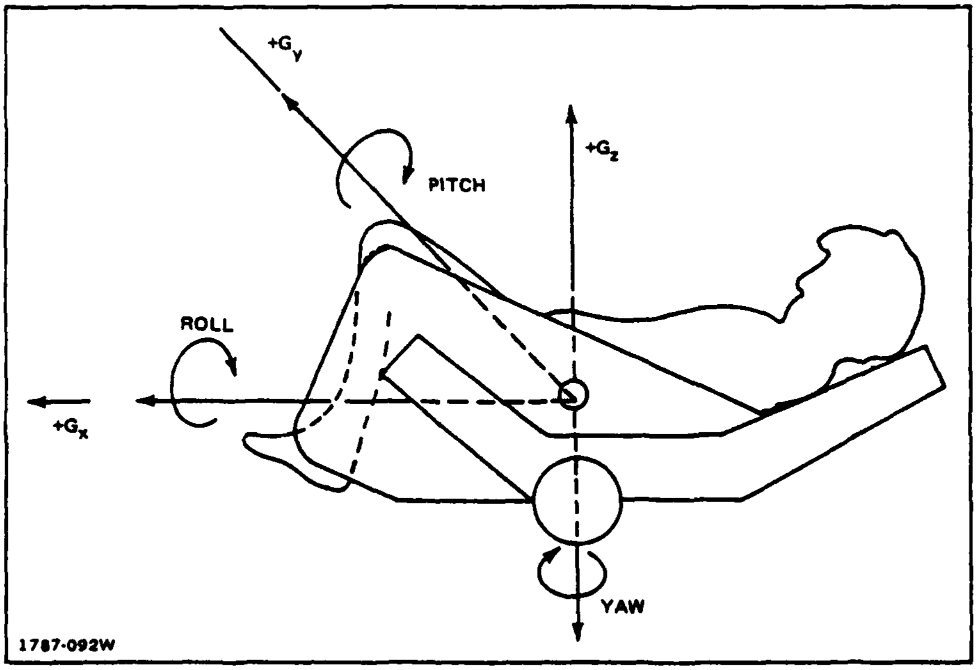


Figure 4-48. Seat/Man Angular Displacements

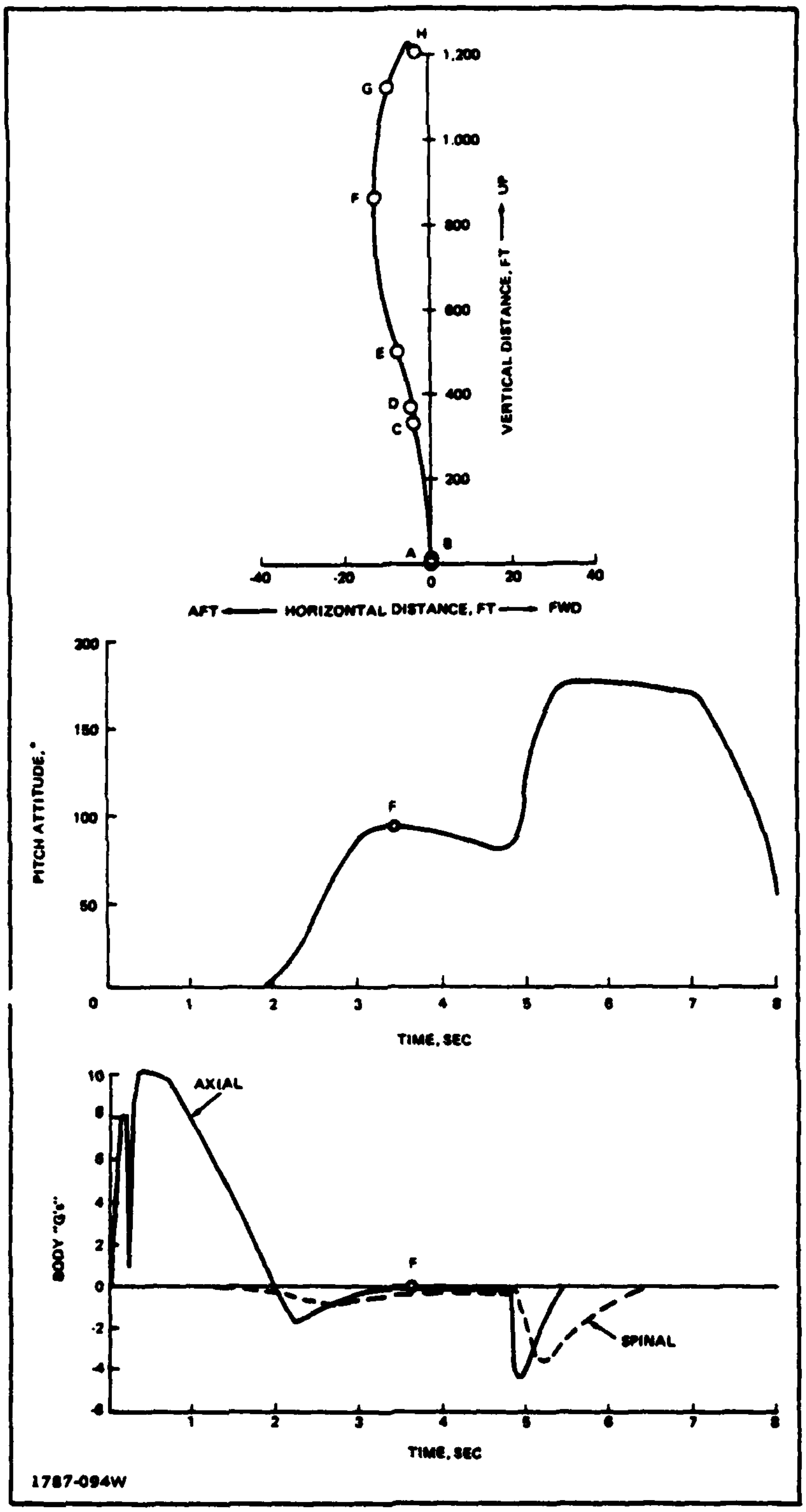


Figure 4-48. Flight Condition 1, Supine Concept Performance

Flight Condition 2 - This flight condition simulates an ejection from an aircraft as it impacts with the ground at a 60° bank angle and a forward velocity of 120 knots. The results of this run are presented in Figure 4-50. The trajectory trace shows an apogee of 1025 feet and a lateral displacement of 450 feet, which were quite adequate to meet the requirements for the ground level ejection. The figure shows the quick roll recovery accomplished by the VSC system where the supine seat rolls 60° in less than 1 second. All angular motions of the seat are stabilized throughout the trajectory and the transitions are smooth between rocket and parachute changeovers. The body G in the three axes are presented and show no unusual problems.

Flight Condition 3 - An escape from a low speed, 10,000-foot-per-minute descent is presented in Figure 4-51. MIL-S-9479B allows 300 feet to accomplish an escape under these conditions; 63 feet is all that the supine seat required for a safe recovery. The seat rocket in the VSC mode maintains a horizontal attitude while the rocket thrust directed vertically-up retards the sink rate and then propels the seat 630 feet high.

Flight Conditions 4, 5, & 6 - Flight conditions 4, 5, and 6 simulate wings level high speed ejections (450, 600, and 687 KEAS) and are presented in Figures 4-52 to 4-54. The ejections for all three flight conditions resulted in safe trajectories. A close-up look at each trajectory indicated a clean seat aircraft separation with the seat passing well above the aircraft tail. The second area of concern was whether the pitch attitude of the seat could be controlled, under these high dynamic pressure conditions, by the VSC and TVC rocket control systems. The figures show that this was the case, and a smooth transition occurred throughout the trajectories. The body G experienced by the crewman were maximum for the high speed case (687 KEAS) shown in Figure 4-54. A maximum level of approximately 10 G along the spinal direction are experienced due to the drag on the seat as it enters the airstream. This decreases until the main chute is inflated and approximately 25 G in the spinal direction are felt through the parachute harness from the opening force of the parachute.

Flight Condition 7 - Flight condition 7 simulates an ejection of a supine seat from an aircraft flying inverted at a speed of 150 knots. The results of this ejection are presented in Figure 4-55. MIL-S-9479B allows a maximum of 200 feet to accomplish a safe ejection under these flight conditions. The supine seat accomplished this task from 66 feet, during which time the roll command

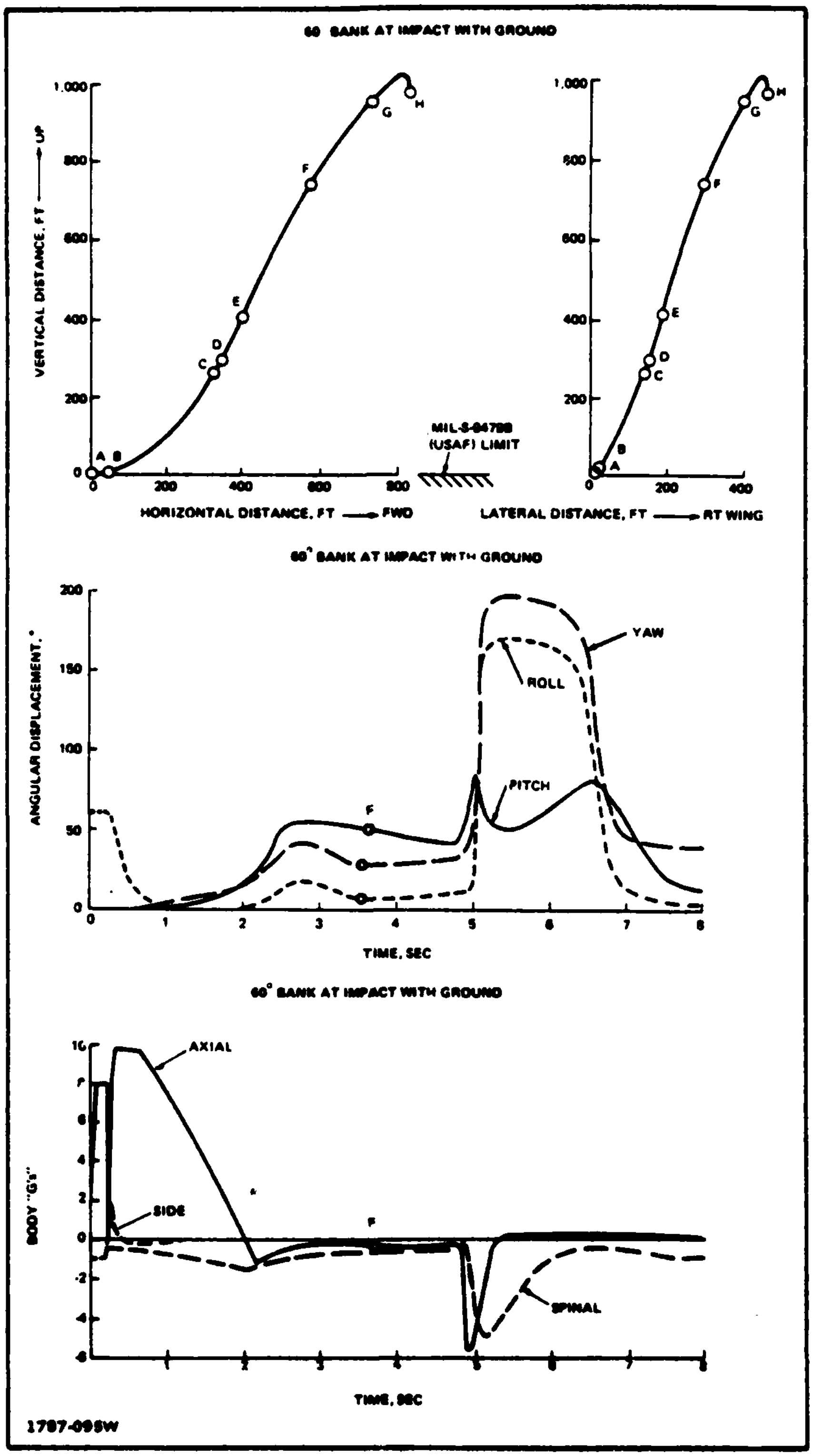


Figure 4-50. Flight Condition 2, Supine Performance

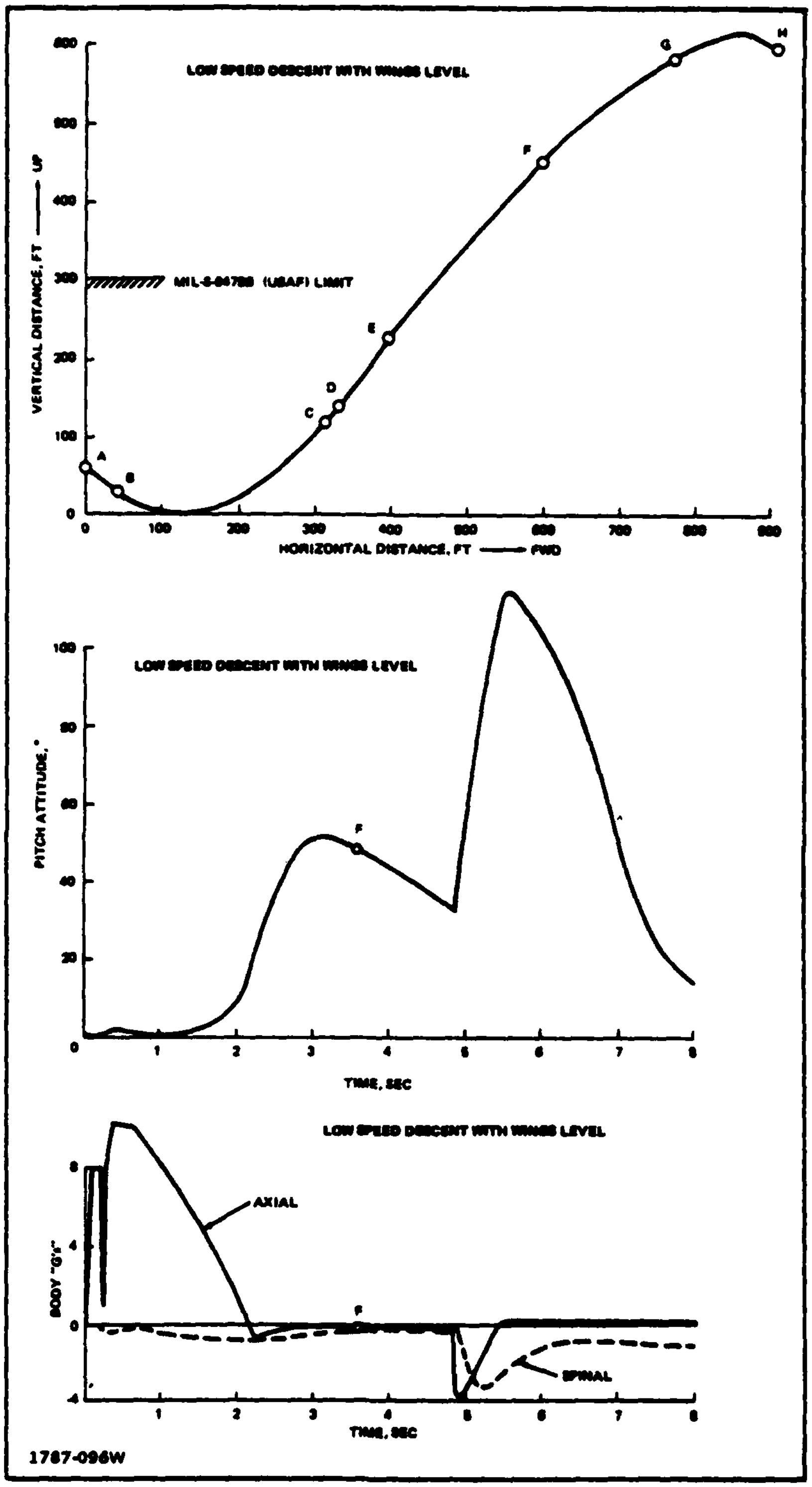


Figure 4-51. Flight Condition 3, Supine Concept Performance

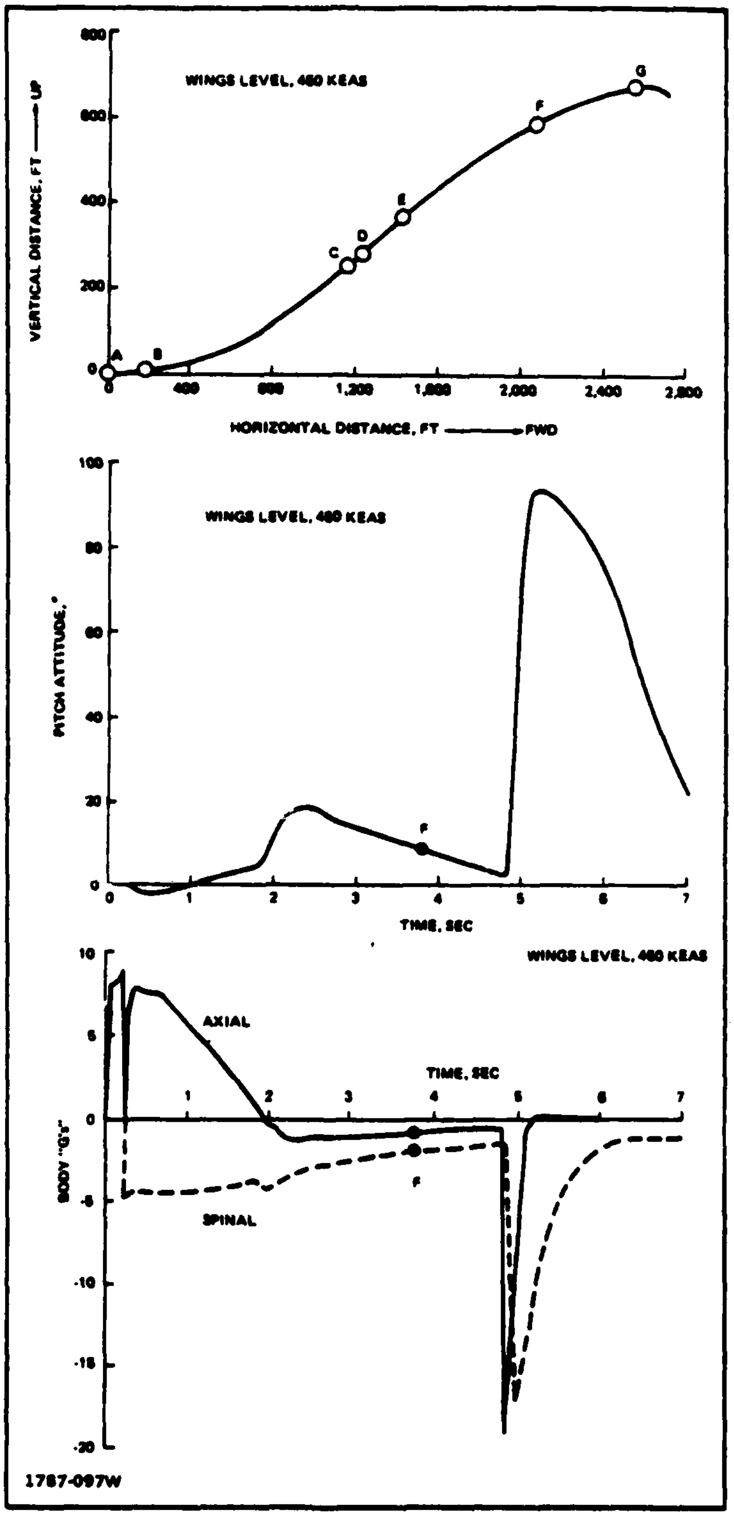


Figure 4-52. Flight Condition 4, Supine Concept Performance

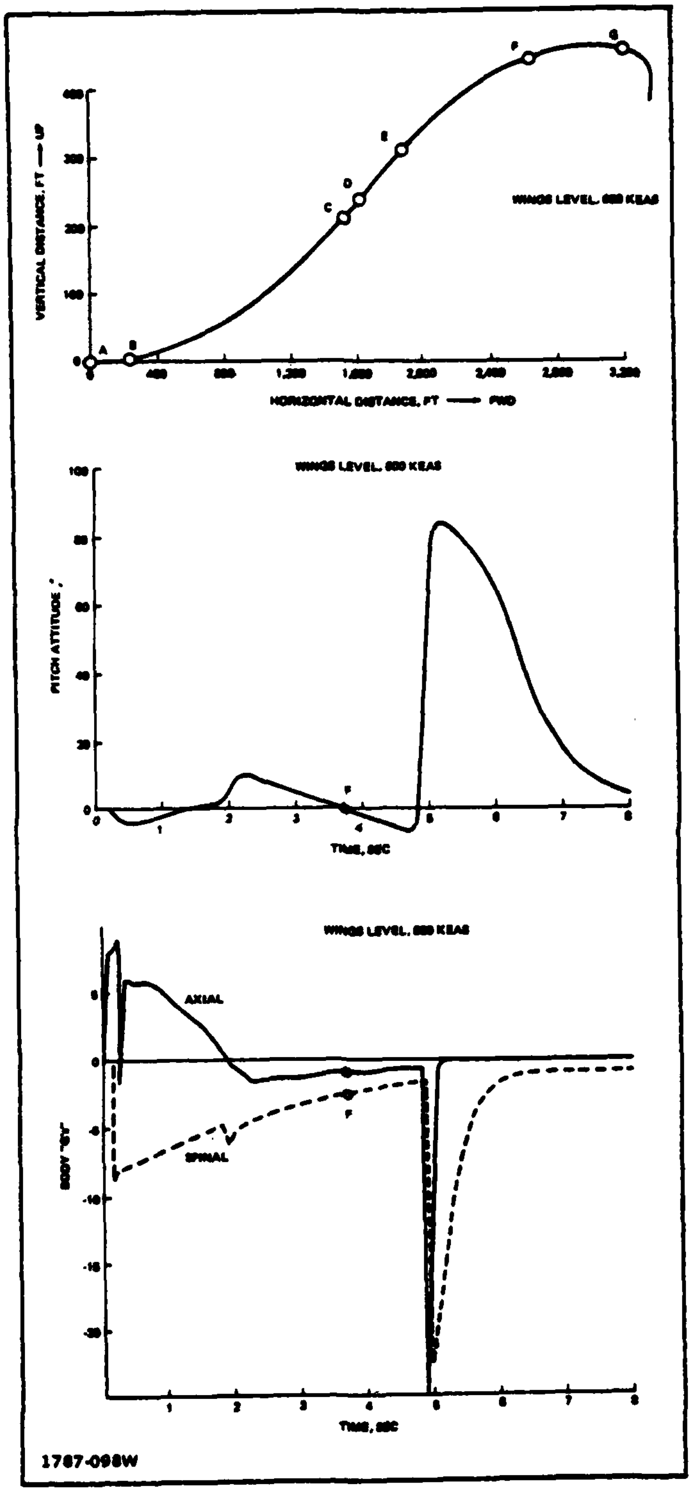


Figure 4-53. Flight Condition 5, Supine Concept Performance

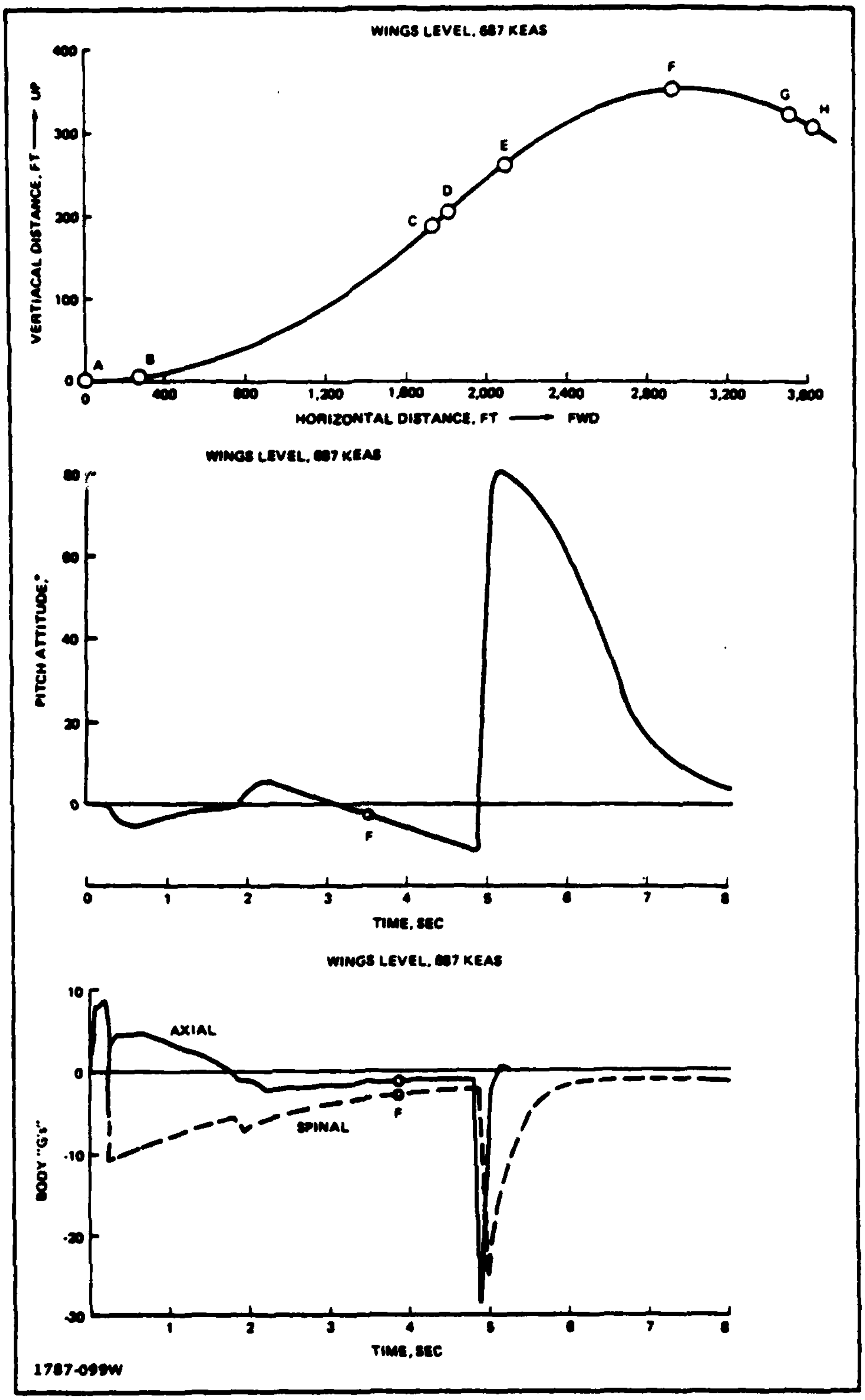


Figure 4-54. Flight Condition 6, Supine Concept Performance

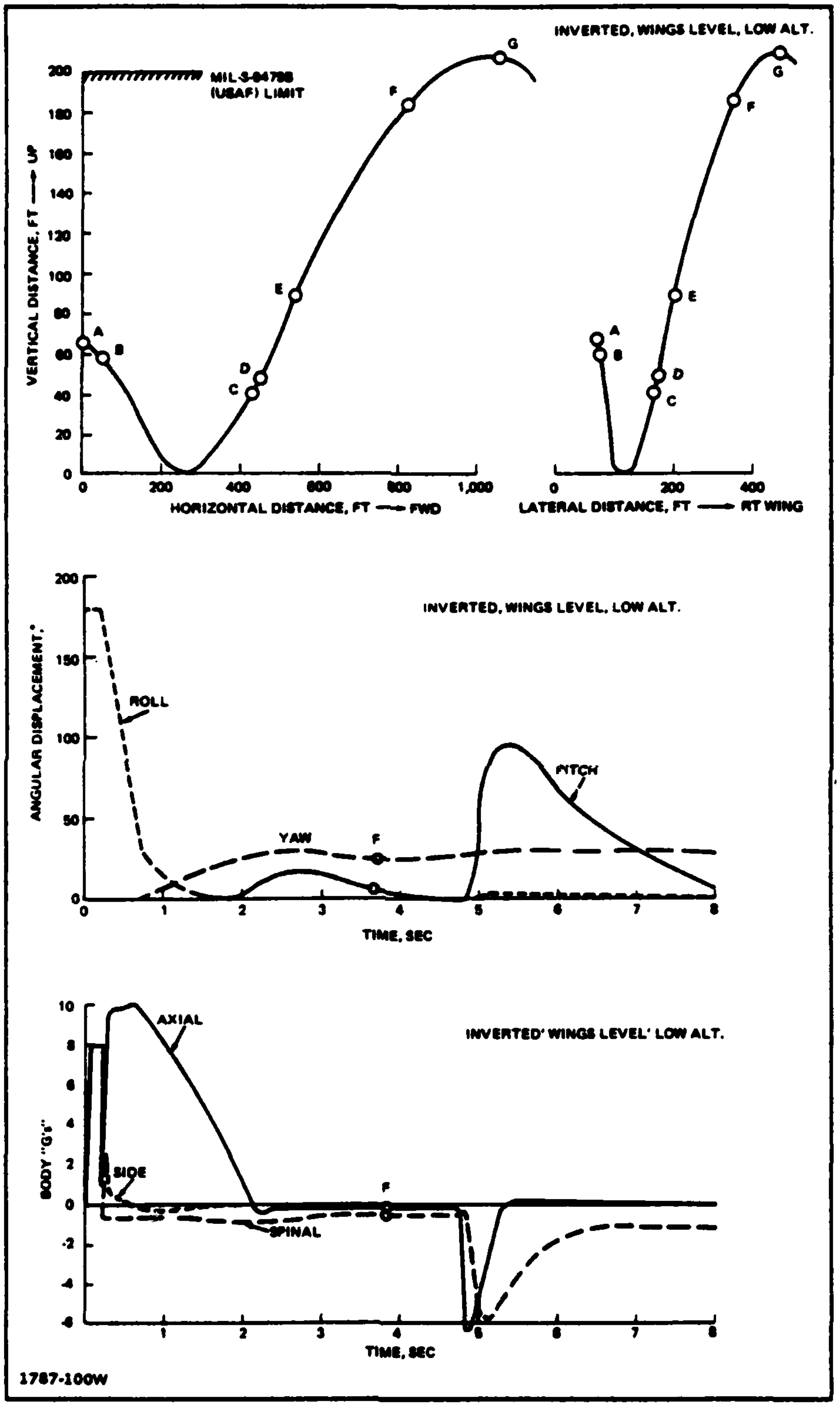


Figure 4-55. Flight Condition 7, Supine Concept Performance

from the autopilot restored the seat to an upright attitude and stopped the descent. The effect of the roll command can be seen clearly in that the seat rolls 180° in less than one second.

Flight Condition 8 - An ejection from a 60° low speed dive condition was simulated and it demonstrated that a minimum altitude of 300 feet is needed for a safe egress under this condition. This is well within the MIL-S-9479B requirement of 500 feet. Figure 4-56 presents the simulated trajectory; it can be seen from this spatial plot that even though the man-seat system never recovered to its initial altitude, the rocket, through its autopilot in the VSC mode, was still able to halt the descent and regain 50 feet in altitude. The figure presents the time history of the pitch attitude of the man-seat system. This plot reflects the quick response of the pitch mode; in a little over 0.5 second, the seat rotates from -60° to 0° attitude.

Flight Condition 9 - Flight condition 9 simulates an escape from an aircraft while in a 450-knot high speed dive and an attitude of 30° nose down. The result of this ejection is shown in Figure 4-57. MIL-S-9479B requires this escape to be initiated at an altitude of less than 500 feet, whereas the supine seat required 595 feet to eject the crewman and safely land him on the ground. At this stage in the development of an ejection seat system it is not uncommon that all specifications are not met. Further optimization of the system will provide results that satisfy the requirements. For example, under adverse attitude and dive conditions, a better blend between the VSC system response and the rocket thrust curve is required, such that the seat will take advantage of the rocket thrust when it is aimed in the proper direction.

Flight Condition 10 - This is a 60° low speed dive with the aircraft banked at 60° right wing down. Figure 4-58 presents the computed trajectory. The minimum altitude required to reach terminal speed was 400 feet. The MIL-S-9479B limit is 550 feet.

Since this condition involved both pitch and roll attitudes, the resultant motion and trajectory were in the lateral-directional was well as in the pitch planes. In this situation, the autopilot sensor, utilizing the data obtained from

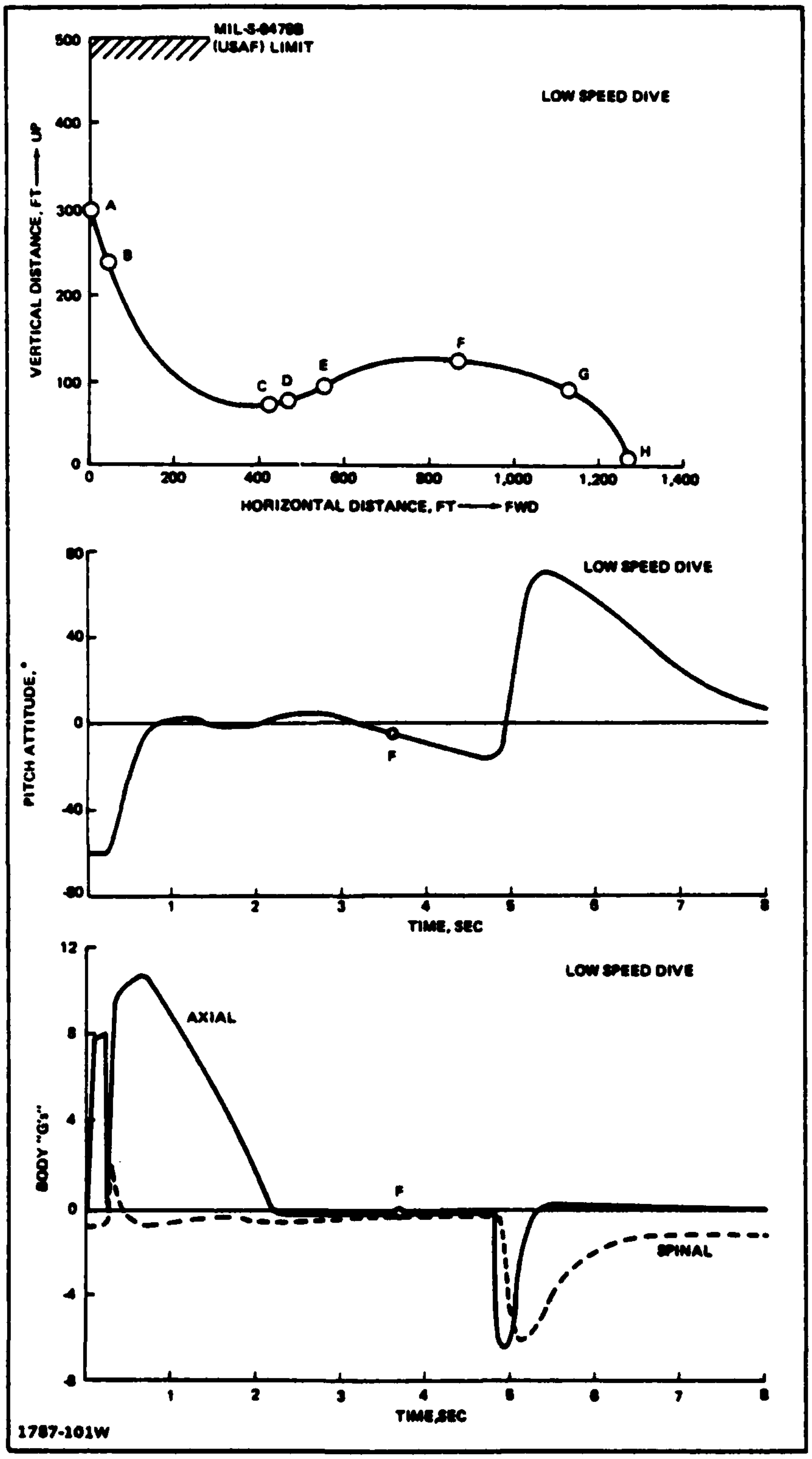


Figure 4-56. Flight Condition 8, Supine Concept Performance

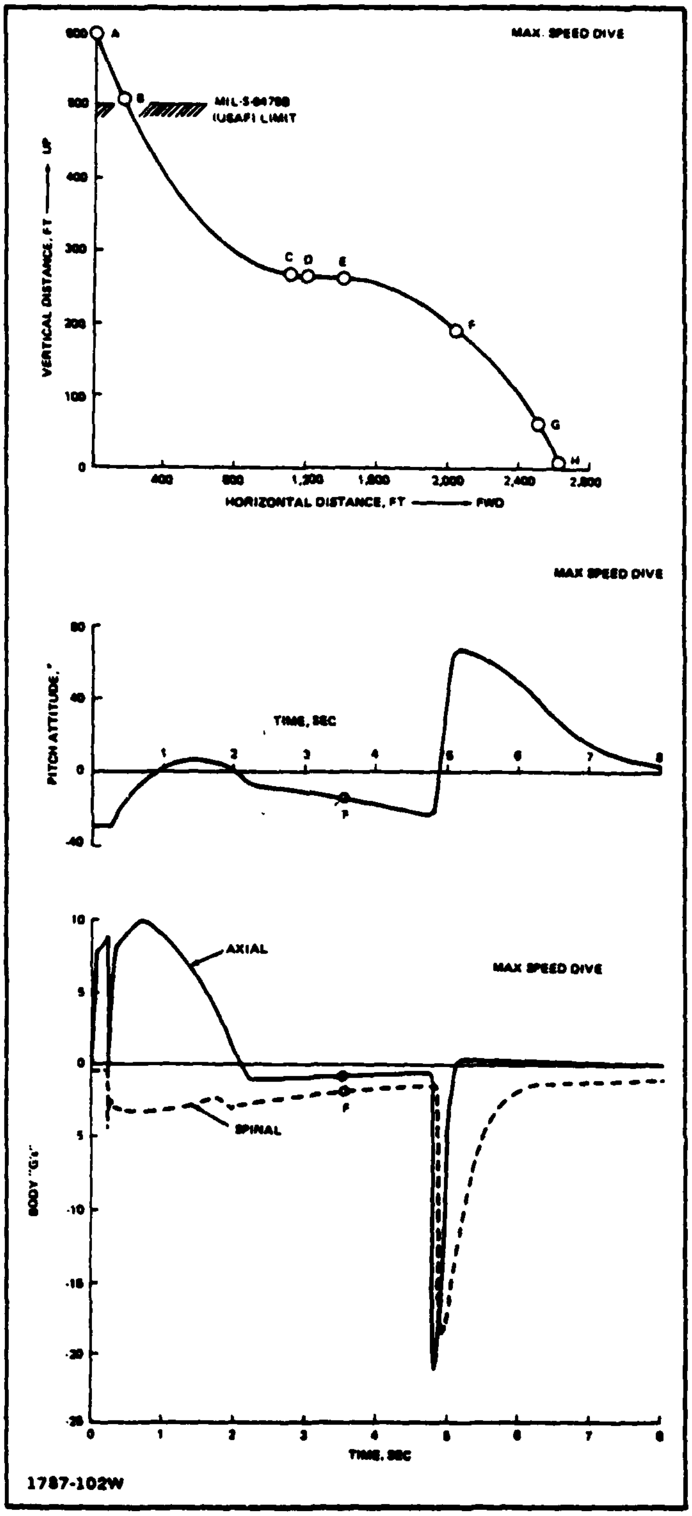


Figure 4-57. Flight Condition 9, Supine Concept Performance

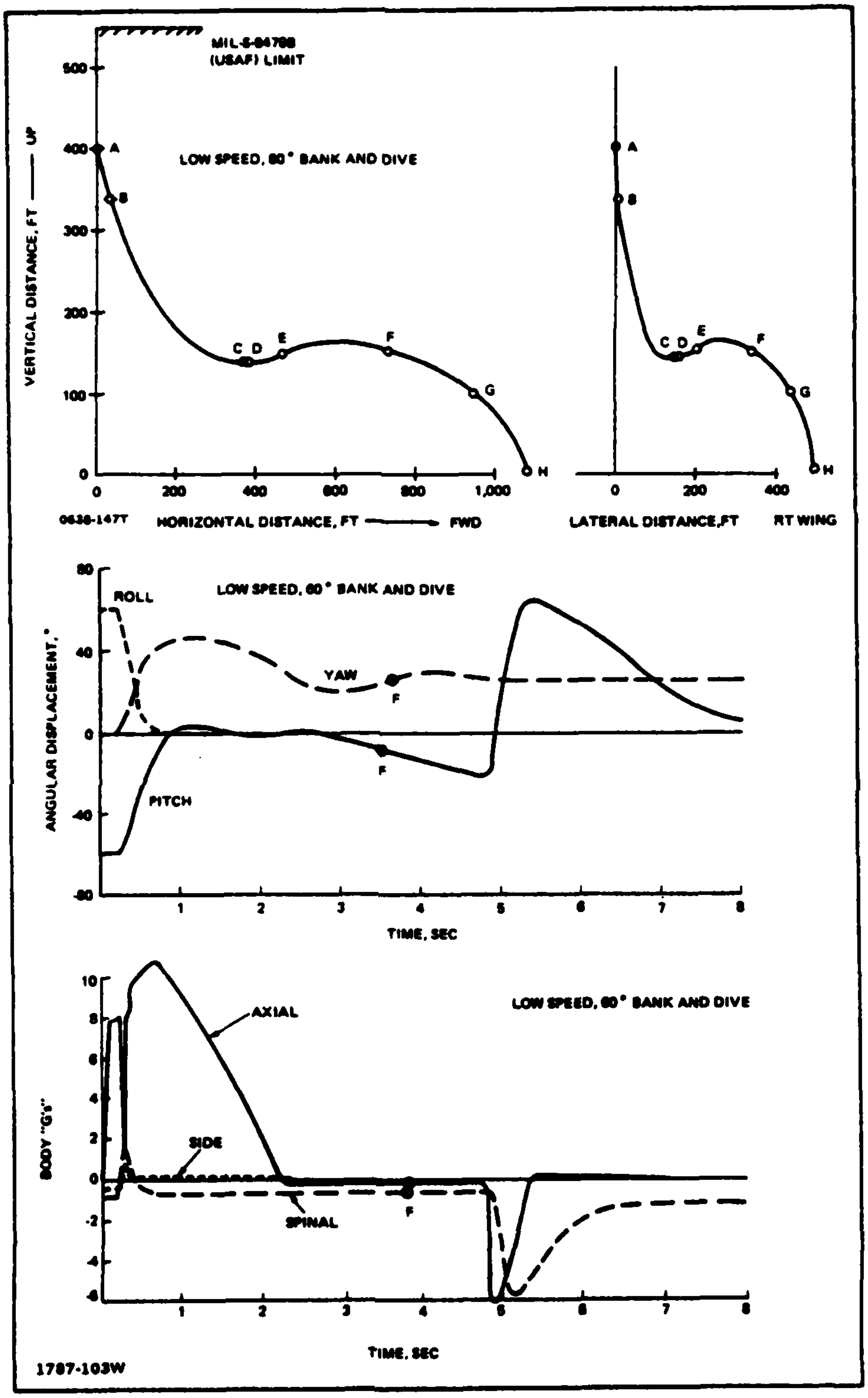


Figure 4-58. Flight Condition 10, Supine Concept Performance

the gyro, issued the appropriate pitch and roll commands to the rocket to rotate the seat to an upright attitude.

The seat attained the desired attitude within 1 second after ejection from the aircraft. Since the autopilot system operates on inertial angular displacements and rates, the roll and pitch commands coupled to bring about significant yawing motion as well.

Flight Condition 11 - This flight condition is the most severe of the series and consists of an aircraft in a 45° dive while inverted at a speed of 250 knots. The results of this simulation is presented in Figure 4-59. The maximum altitude allowed by MIL-S-9479B for this flight condition is 500 feet. From the computer calculation it was determined that the supine seat requires 900 feet to effect a safe escape. Once again, this deficiency can be improved upon by means of optimizing the system. The figure shows the time histories of the seats' angular displacement in pitch, roll, and yaw. The seat is rolled and pitched to an upright attitude in less than 1 second where the roll motion is completed first, followed by the pitch. The seat yaws as a result of the coupling action between the pitch and roll motion; however, this does not constitute a problem in terms of the escape sequence.

4.6.2 Supine Escape Systems Design

The preliminary design of the supine escape system was based on the geometry established in the MSLPC baseline configuration. Major subsystems consist of the supine seat assembly, catapult/boost system, and windshield/canopy assembly shown in Figure 4-60. The supine seat assembly and subsystem components are shown in Figure 4-61.

4.6.2.1 Escape System Operation - The escape sequence (Figure 4-62) is initiated by actuation of either or both side-mounted ejection control handles which fires L.H. and R.H. gas generators (Figure 4-63). The gas travels to the safe and arm device located on the headrest, the aircraft disconnect behind the headrest and the pilot restraint system. The gas actuates the shoulder harness restraint reel and limb restraint reel (Figure 4-64), taking up the slack in the harness and limb cords (Figure 4-65) and pulling the feet into a recess in the forward end of the seat and the arms into the side of the seat without breaking the hand grips. Inflatable body containment components are actuated simultaneously.

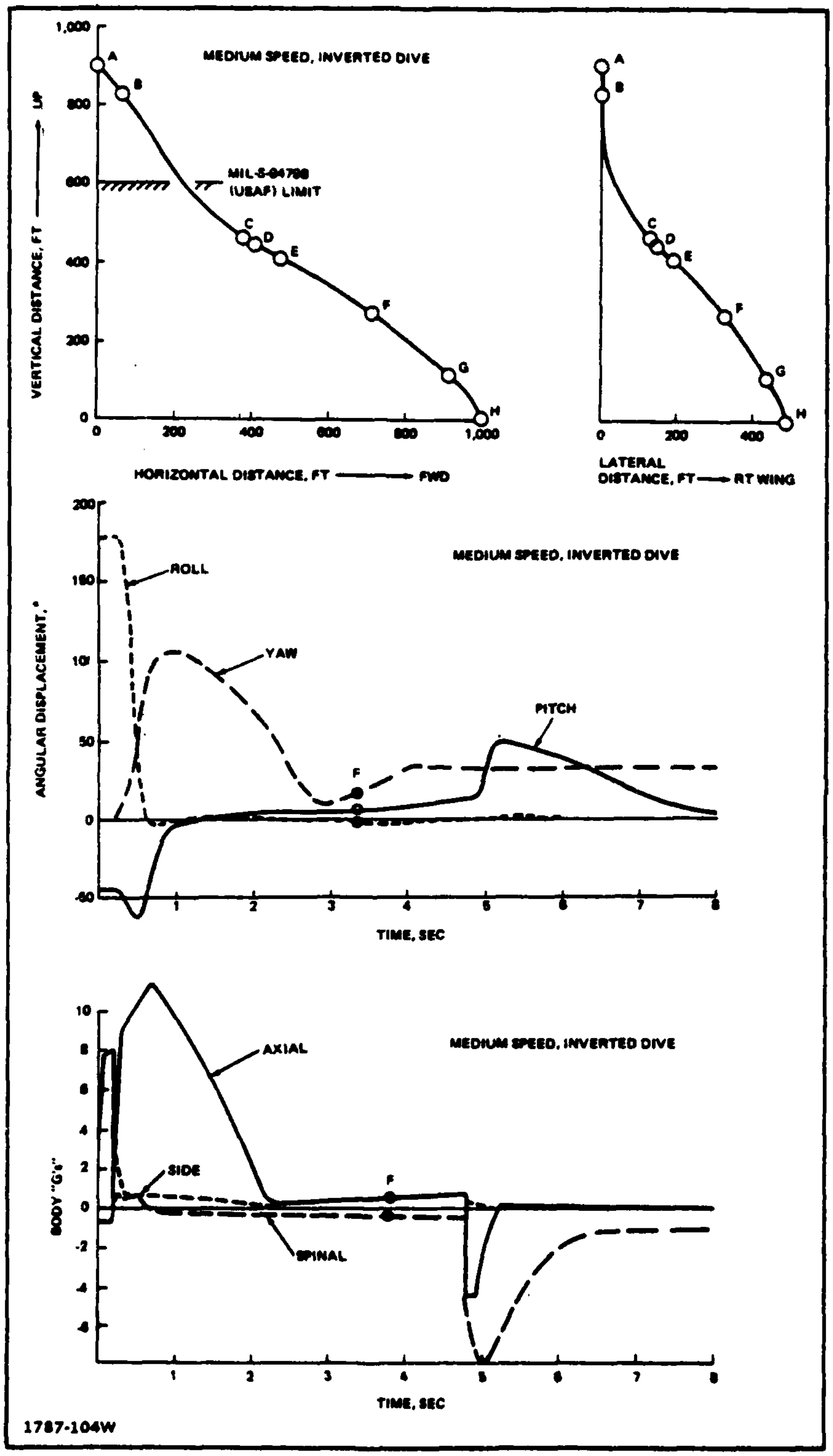
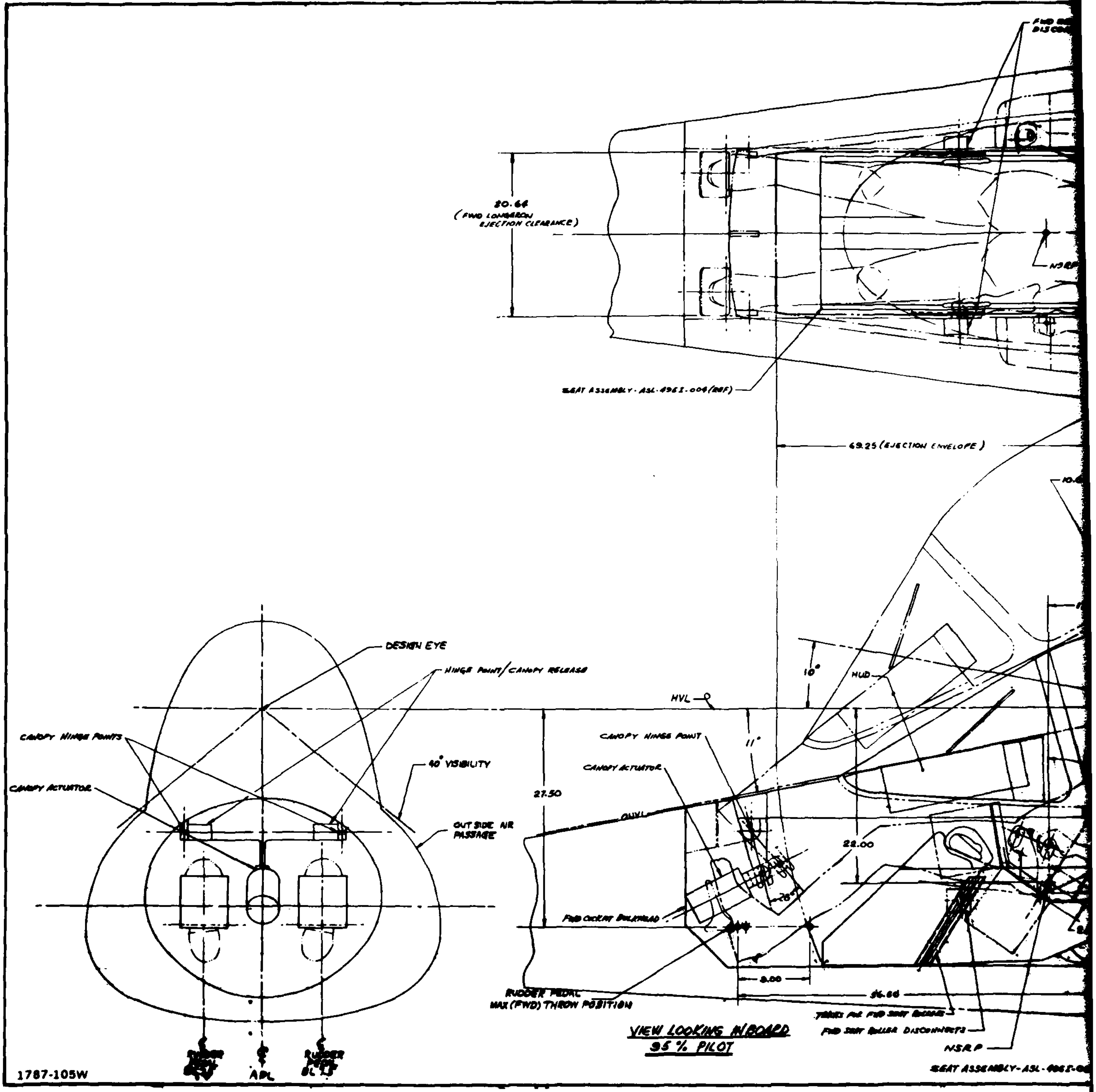
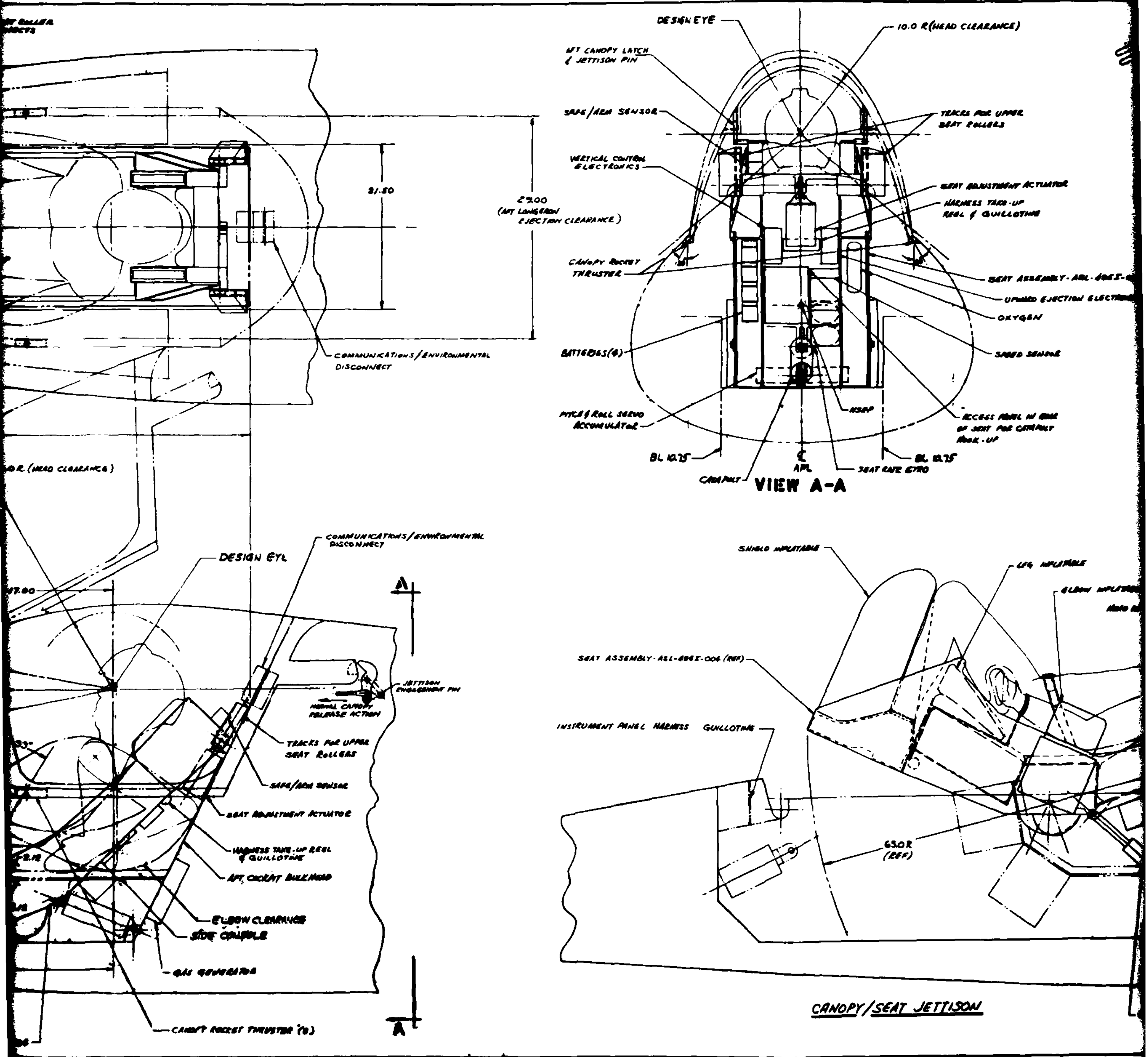


Figure 4-59. Flight Condition 11, Supine Concept Performance



20.64
(FWD LONGERON EJECTION CLEARANCE)
SEAT ASSEMBLY - ASL-4961-004 (REF)
69.25 (EJECTION ENVELOPE)
DESIGN EYE
HINGE POINT/CANOPY RELEASE
CANOPY HINGE POINTS
40° VISIBILITY
CANOPY ACTUATOR
OUTSIDE AIR PASSAGE
HVL
10°
HUD
11°
CANOPY HINGE POINT
CANOPY ACTUATOR
27.50
22.00
FWD COCKPIT BULKHEAD
8.00
36.66
RUDDER PEDAL
MAX (FWD) THROW POSITION
FWD SEAT ROLLER DISCONNECTS
NSRP
VIEW LOOKING INBOARD
95% PILOT
ABL

1787-105W



DESIGN EYE
10.0 R (HEAD CLEARANCE)
AFT CANOPY LATCH & JETTISON PIN
SAFE/ARM SENSOR
TRACKS FOR UPPER SEAT ROLLERS
VERTICAL CONTROL ELECTRONICS
SEAT ADJUSTMENT ACTUATOR
HARNESS TAKE-UP REEL & GUILLOTINE
CANOPY ROCKET THRUSTER
UPWARD EJECTION ELECTRONICS
OXYGEN
BATTERIES (4)
SPEED SENSOR
PITCH & ROLL SERVO ACCUMULATOR
HSGP
ACCESS PANEL IN REAR OF SEAT FOR CATAPULT HOOK-UP
BL 10.75
APL
CATAPULT
SEAT RATE GYRO
VIEW A-A
21.50
29.00 (AFT LONGERON EJECTION CLEARANCE)
COMMUNICATIONS/ENVIRONMENTAL DISCONNECT
(HEAD CLEARANCE)
DESIGN EYE
JETTISON ENGAGEMENT PIN
NORMAL CANOPY RELEASE ACTION
SAFE/ARM SENSOR
SEAT ADJUSTMENT ACTUATOR
HARNESS TAKE-UP REEL & GUILLOTINE
AFT COCKPIT BULKHEAD
ELBOW CLEARANCE
SIDE CONSOLE
GAS GENERATOR
CANOPY ROCKET THRUSTER (2)
A
A
SHIELD INFLATABLE
LEG INFLATABLE
ELBOW INFLATABLE
SEAT ASSEMBLY-ASL-496I-006 (REF)
INSTRUMENT PANEL HARNESS GUILLOTINE
63.0 R (REF)
CANOPY/SEAT JETTISON

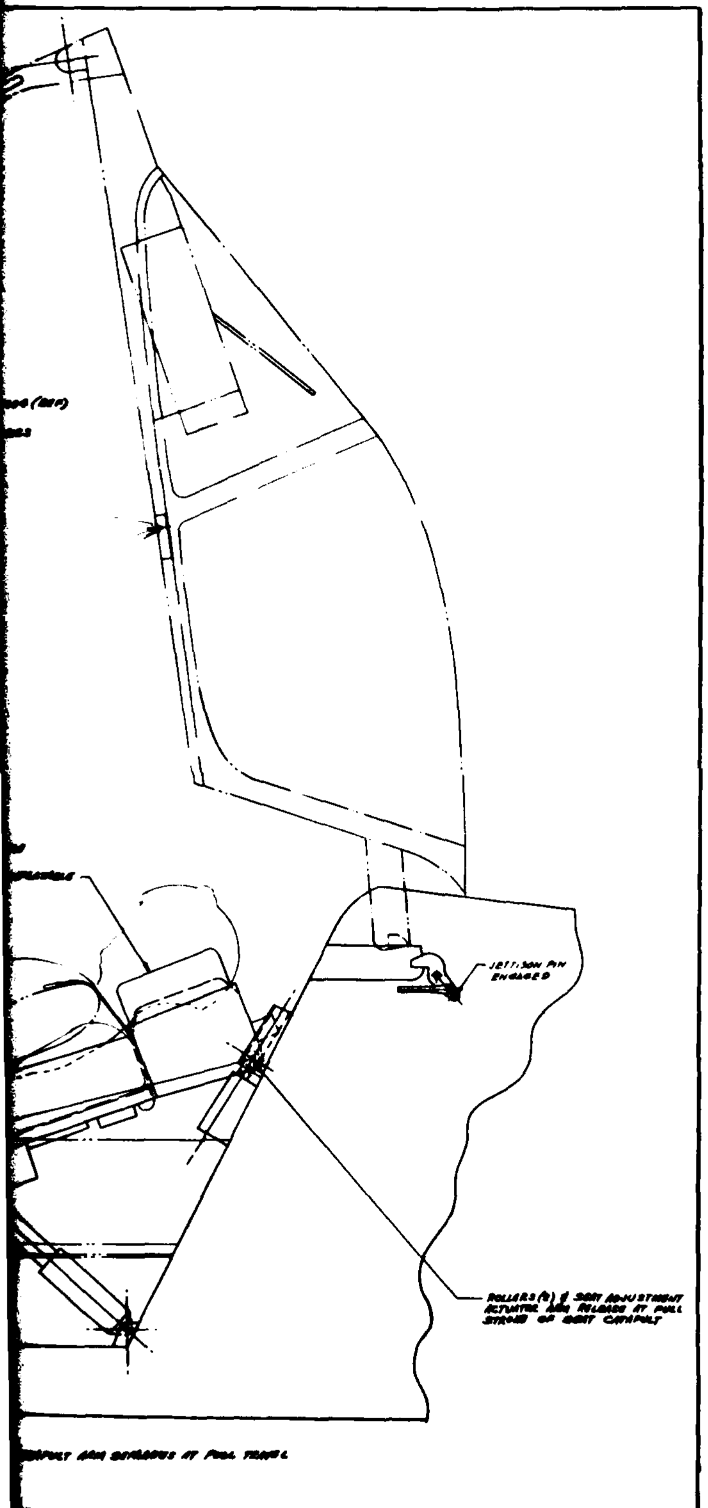
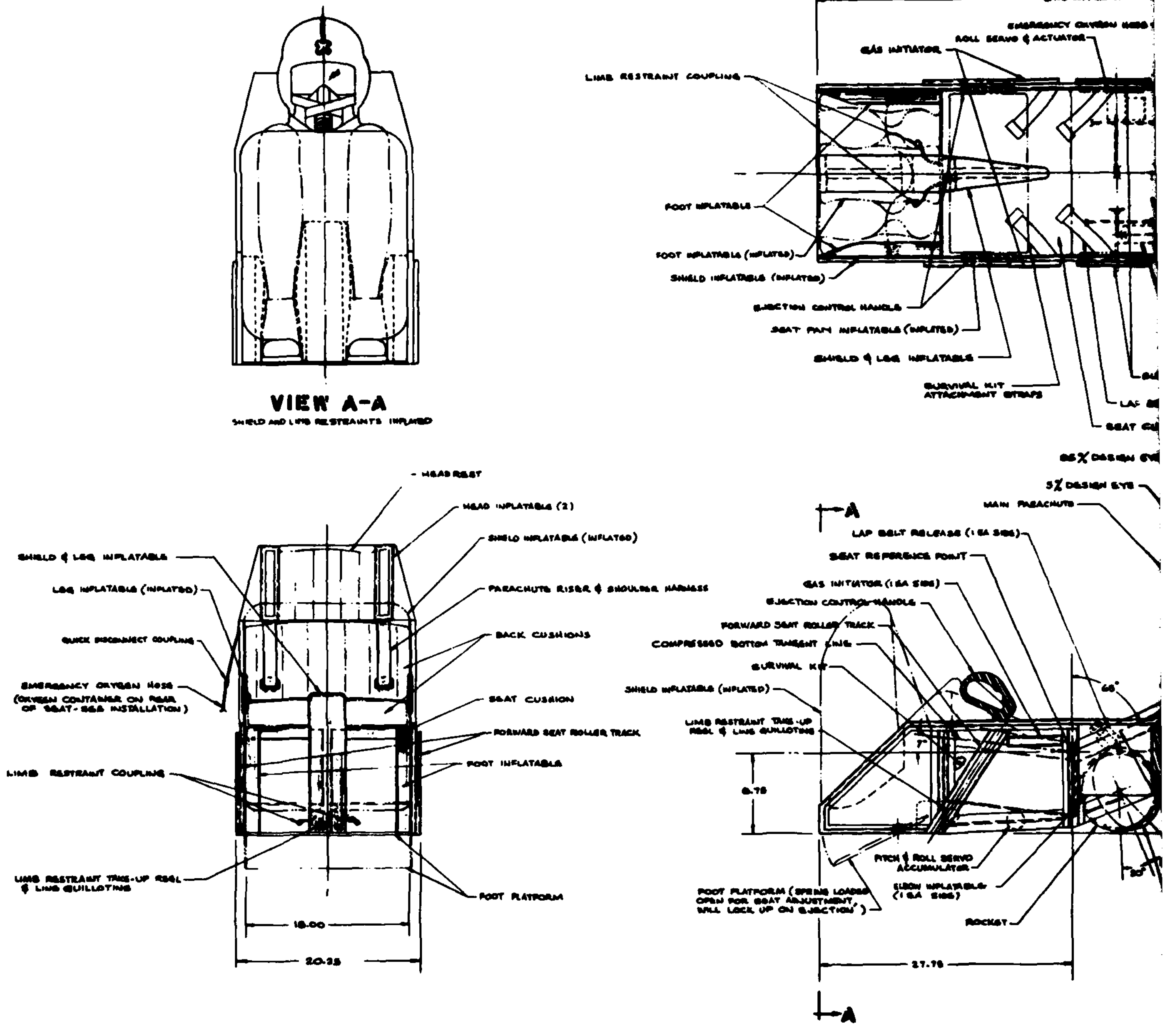


Figure 4-60. Supine Escape System Installation

3



VIEW A-A
61.0 APPROX.
EMERGENCY OXYGEN HOSE
ROLL SERVO & ACTUATOR
GAS INITIATOR
LIMB RESTRAINT COUPLING
FOOT INFLATABLE
FOOT INFLATABLE (INFLATED)
SHIELD INFLATABLE (INFLATED)
EJECTION CONTROL HANDLE
SEAT PAN INFLATABLE (INFLATED)
SHIELD & LEG INFLATABLE
SURVIVAL KIT ATTACHMENT STRAPS
95% DESIGN EYE
5% DESIGN EYE
MAIN PARACHUTE
LAP BELT RELEASE (1 EA SIDE)
SEAT REFERENCE POINT
GAS INITIATOR (1 EA SIDE)
FORWARD SEAT ROLLER TRACK
COMPRESSED BOTTOM TANGENT LINE
SURVIVAL KIT
HEADREST
HEAD INFLATABLE (2)
LEG INFLATABLE (INFLATED)
PARACHUTE RISER & SHOULDER HARNESS
QUICK DISCONNECT COUPLING
BACK CUSHIONS
EMERGENCY OXYGEN HOSE (OXYGEN CONTAINER ON REAR OF SEAT-SEE INSTALLATION)
SEAT CUSHION
LIMB RESTRAINT TAKE-UP REEL & LINE GUILLOTINE
FOOT PLATFORM
18.00
20.25
6.75
27.75
60°
PITCH & ROLL SERVO ACCUMULATOR
ELBOW INFLATABLE (1 EA SIDE)
FOOT PLATFORM (SPRING LOADED OPEN FOR SEAT ADJUSTMENT, WILL LOCK UP ON EJECTION)
ROCKET
A

1787-106W

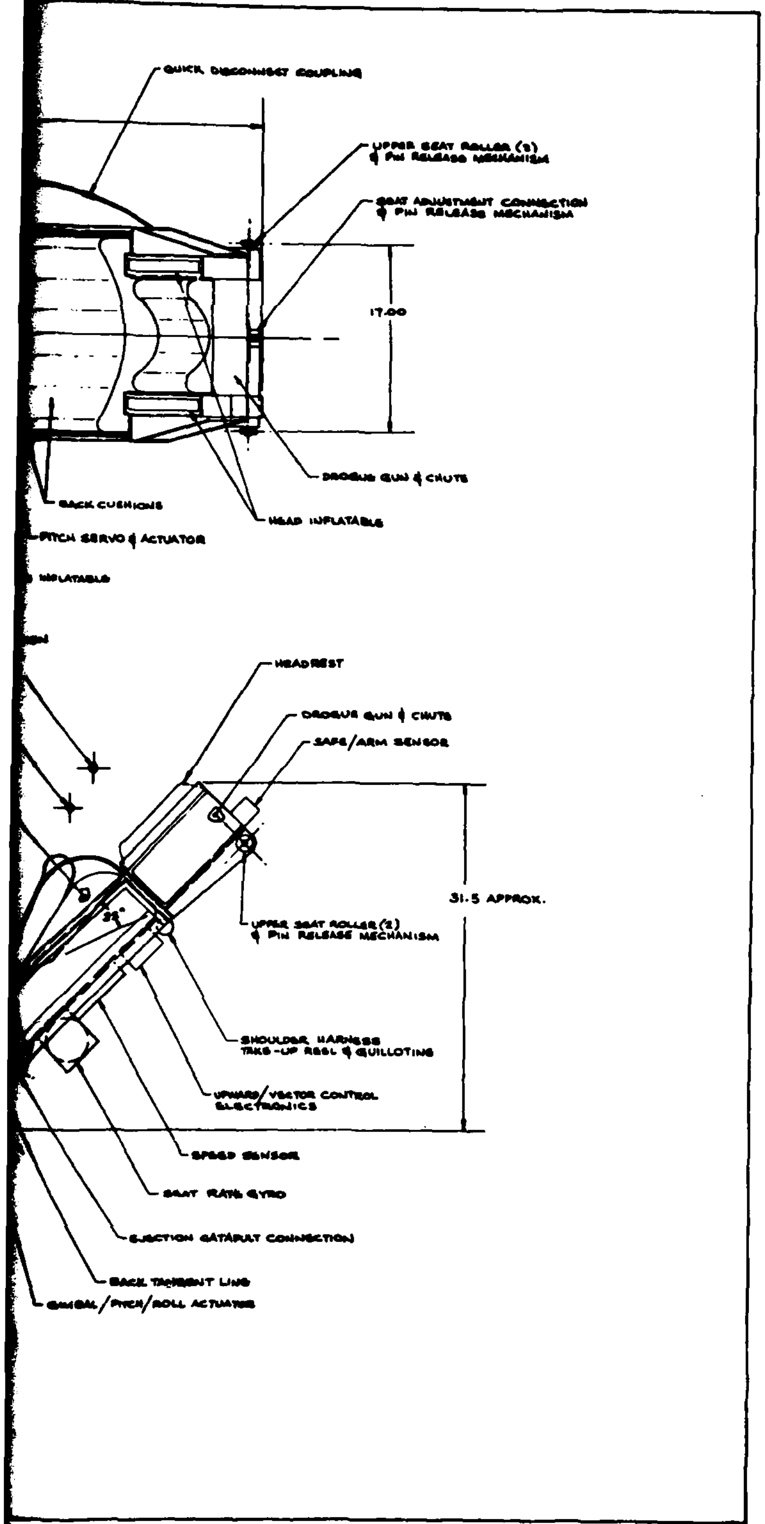


Figure 4-61. Supine Seat Assembly

2

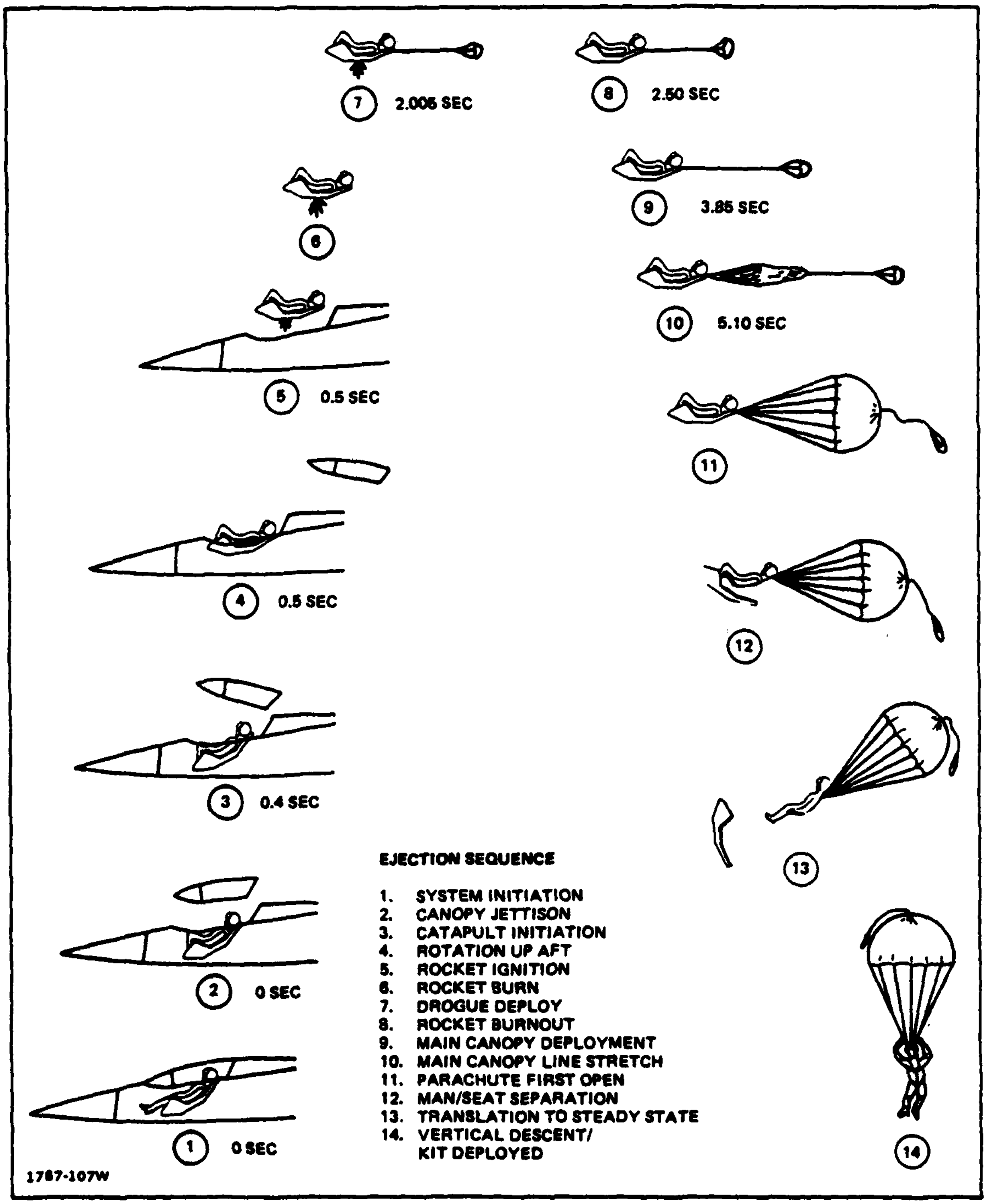


Figure 4-62. Ejection Sequence

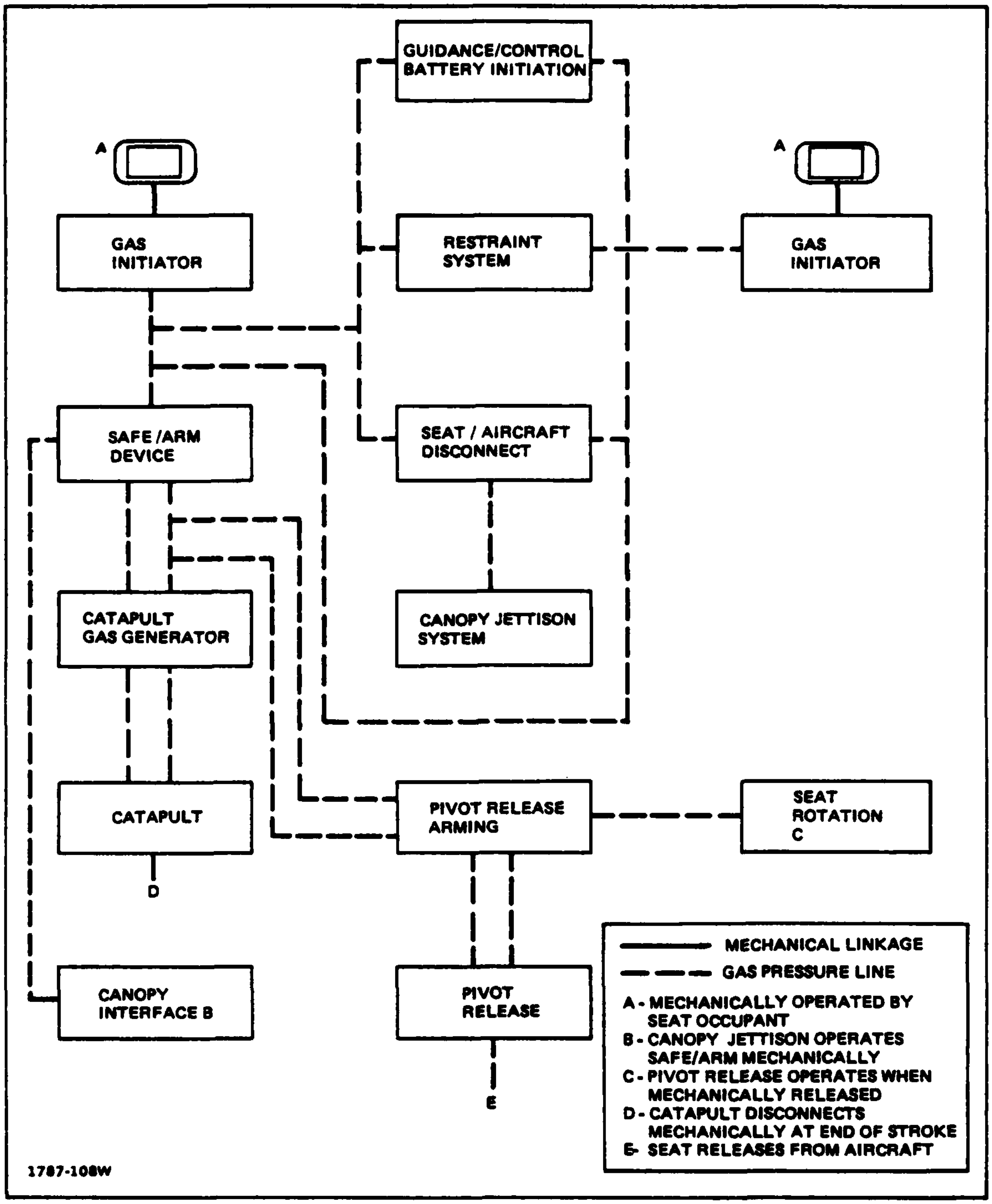


Figure 4-63. System Schematic, Escape Initiation

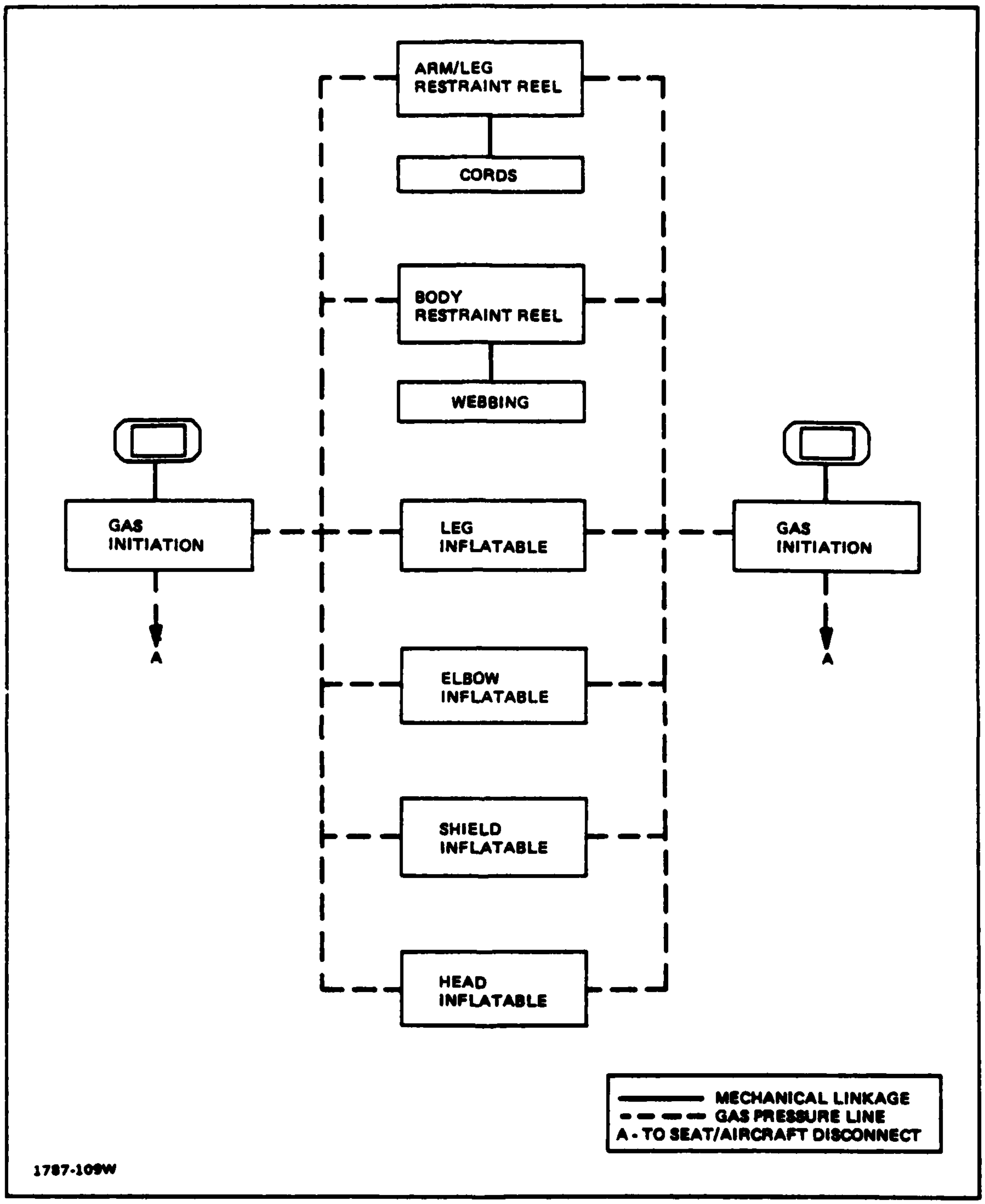


Figure 4-64. System Schematic, Body Restraint

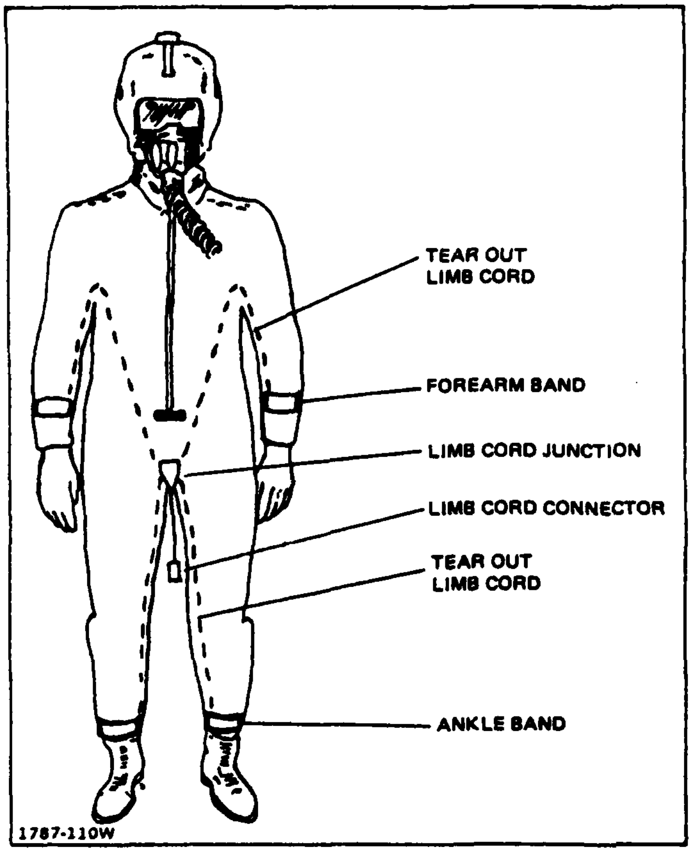


Figure 4-65 Integrated Limb Cord Flight Suit

System initiation gas continues traveling from the seat/aircraft disconnect to the forward canopy hinge pins, actuating the disengagement of both (Figure 4-66). The rocket thrusters located in each side of the canopy frame are initiated and the windshield, instrument panel, and canopy are disconnected from the aircraft, rotating aft about integral retention points. A predetermined point in the separation path of the canopy is sensed by the safe/arm unit which allows the catapult gas generator to fire.

The catapult drives the seat upward in an arc rotating about the upper seat adjustment rollers which are fixed in place by the seat actuator. As the seat begins separation, an attached cable breaks the seat/aircraft disconnect and activates a gas generator which initiates the drogue gun timer, parachute release timer, and the rocket motor (Figure 4-67). The attached cable is fully extended as the seat reaches a position parallel to the aircraft longitudinal axis and actuates a gas-operated roller pin release mechanism which disengages

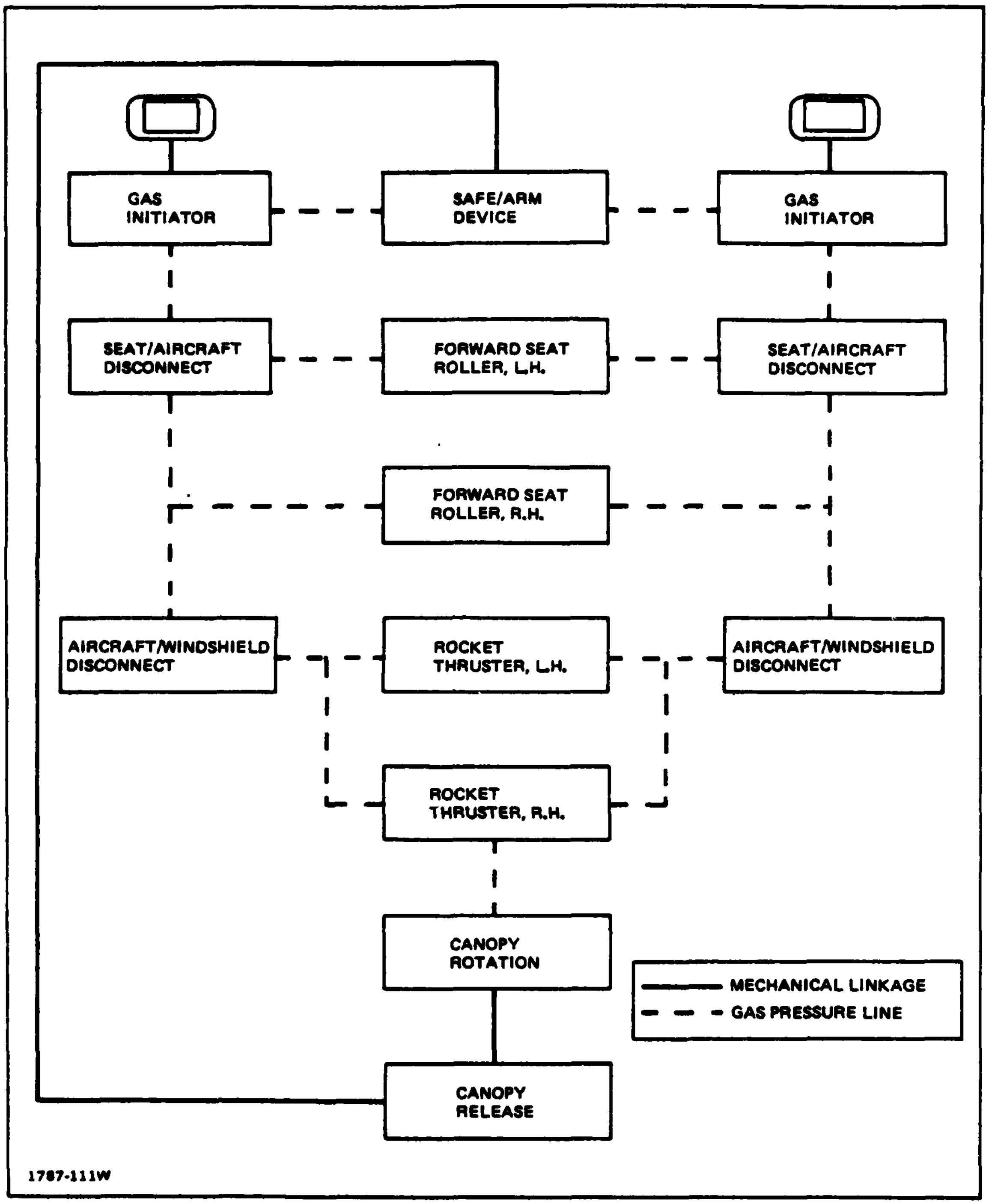


Figure 4-66. System Schematic, Canopy Jettison

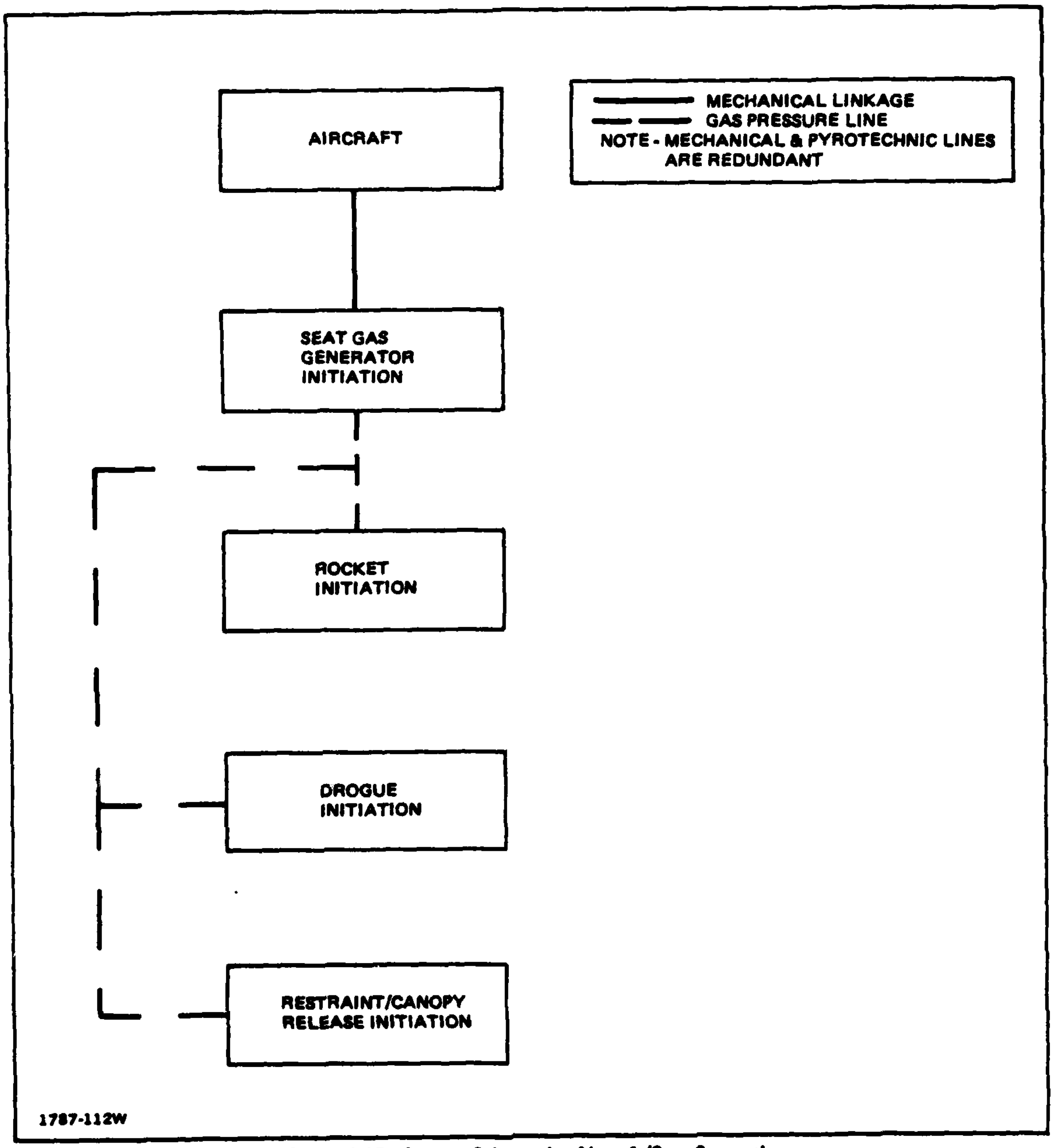


Figure 4-67. System Schematic, Aircraft/Seat Separation

the seat-man mass for free flight under the guidance and control system (Figure 4-68).

The aircraft inertial platform is connected electrically to the ejection seat via the seat/aircraft disconnect. A rate gyro on the seat operates continually when the aircraft is in operation. Two batteries are utilized for instantaneous electrical requirements and two additional batteries attain full strength by the time the seat has rotated to the launch position. A speed sensor detects aircraft speed up to the time of seat/aircraft disconnect separation. If the aircraft speed is below 600 knots, the seat will be locked in the vertical steering mode; if the aircraft speed is above 600 knots the seat will be locked in the vector control mode. Either the upward ejection electronics or vector control electronics will send signals to the roll and pitch servos that in turn will operate the roll and pitch actuators and direct the rocket to thrust in a prescribed manner. If the circuitry malfunctions, the electronics will lock the servo unit in the neutral position.

The drogue gun fires at a predetermined time and the drogue chute is deployed. After rocket burnout and deceleration, the main parachute and restraint release systems are activated (Figure 4-69). A gas generator unlocks the lap belt on both sides and activates a guillotine, severing the limb restraint lines and shoulder restraint webbing. As the drogue is released, the main parachute is withdrawn and deployed. With all body restraints released, main chute deceleration causes the seat and man to separate and, on attaining a steady state condition, the survival kit is deployed.

4.6.2.2 Structural Assembly - The seat structure is composed of aluminum sheet, angles, and extrusions. The assembly has been compartmentalized to accommodate the rocket motor, survival kit, main and drogue parachutes. Support surfaces are provided for the head, back, and buttocks. Seat adjustment tracks are incorporated at the front end and rollers are incorporated at the upper aft end to optimize their contribution to the unique structural and operational requirements. A foot recess and an inflatable air blast shield are an integral part of the forward end.

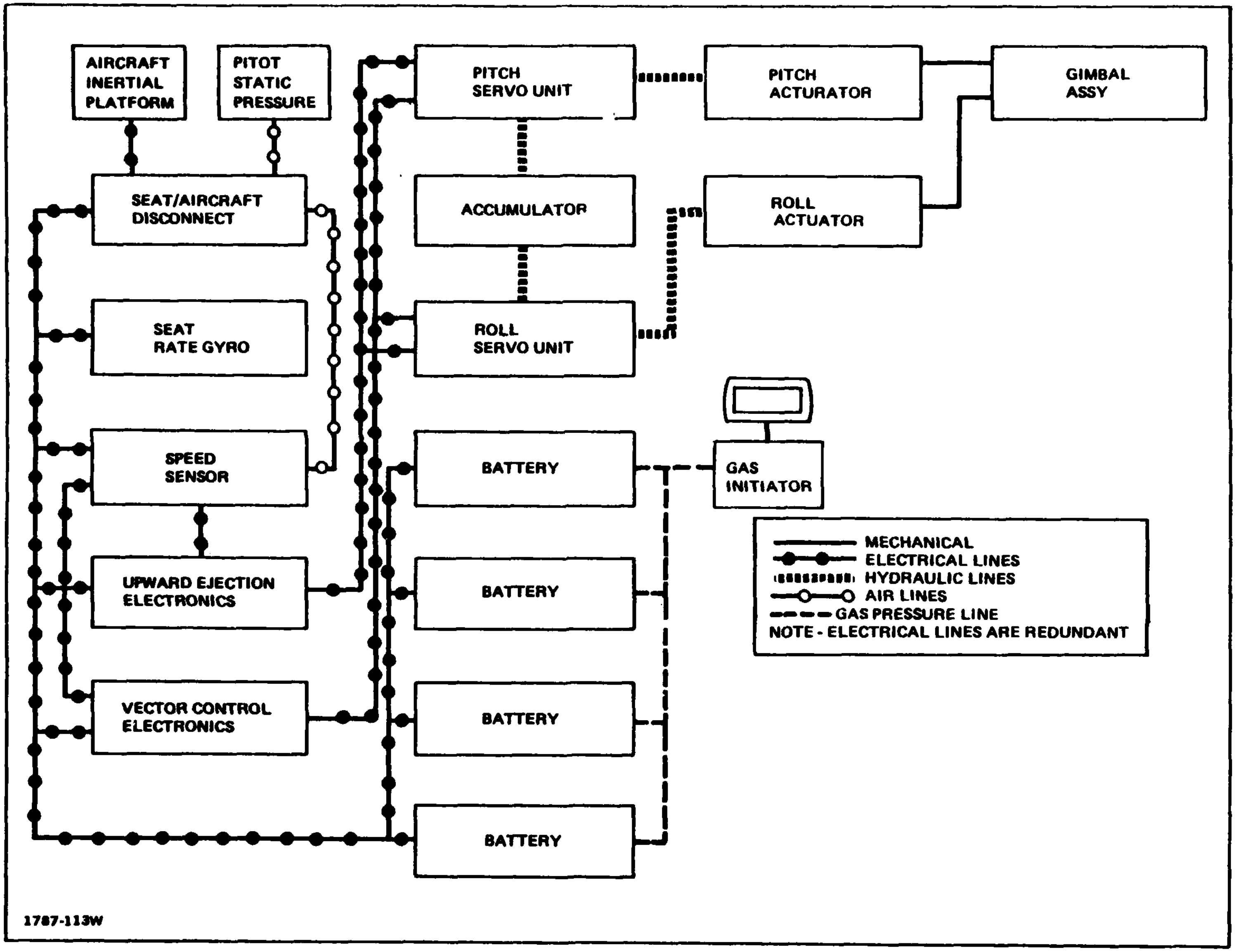


Figure 4-68. System Schematic, Guidance and Control

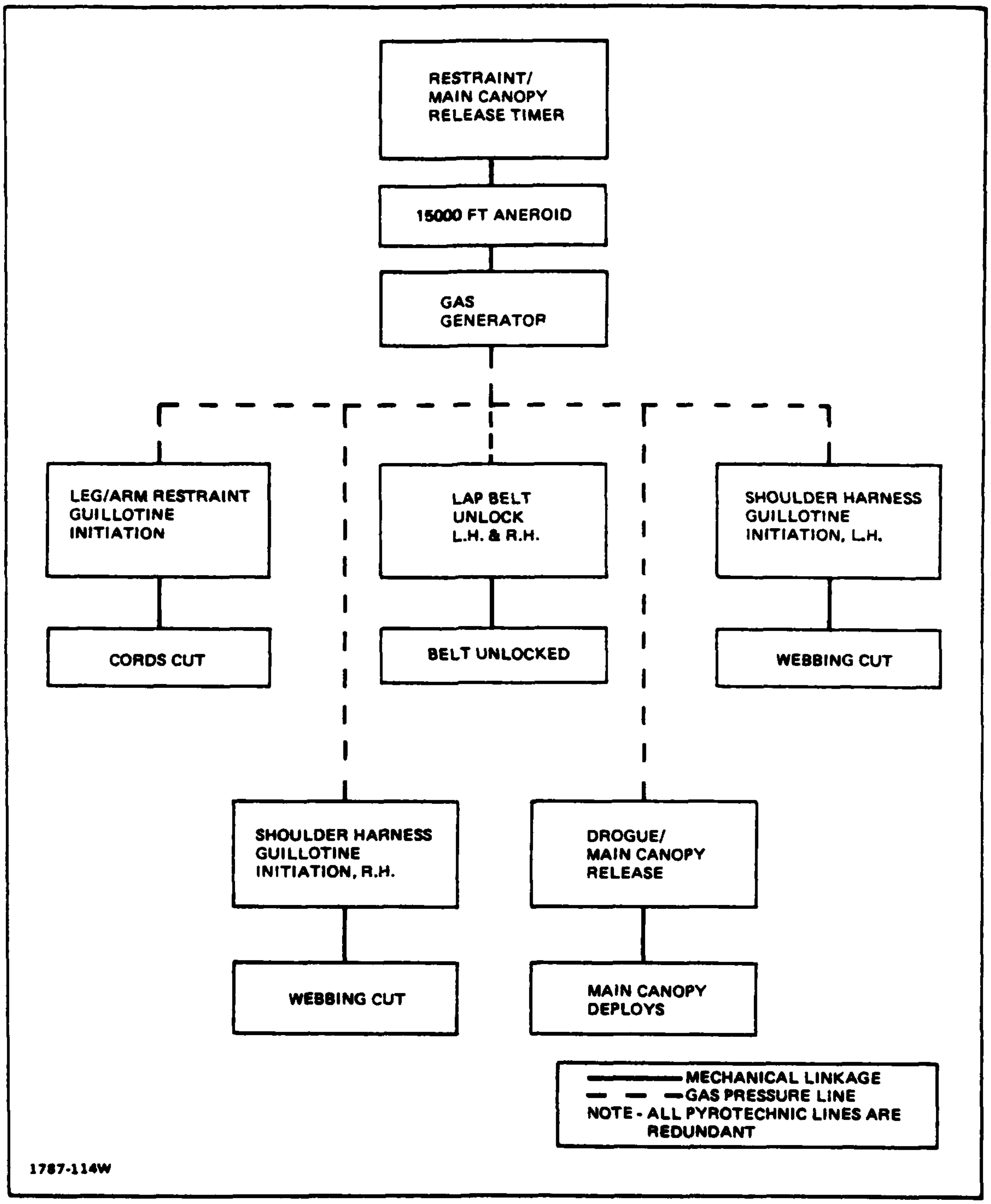


Figure 4-69, System Schematic, Restraint Release

Although the design of a supine ejection seat concept is unprecedented, the use of many off-the-shelf components is possible. The extent to which existing hardware can be used directly effects the unit cost and, more significantly, the development cost. The following off-the-shelf components were identified for use during the supine escape system preliminary design:

- Survival kit items
- Main (28-foot-diameter) parachute
- Drogue (2-foot-diameter) parachute
- Ejection initiation handles
- Drogue gun
- Timing devices
- Batteries
- Rate Gryo
- Rocket thrusters (for a/c canopy unit jettison)
- Gas generators
- Gas initiators
- Drogue release hardware
- Speed sensors
- Guillotine.

4.6.2.3 Seat System Structural Strength - The basic seat system has been examined with respect to the primary requirements of MIL-S-9479B (USAF), Paragraphs 3.6.2.2g (Crash Condition) and 3.6.2.2h (Ejection Airload Condition). Analysis has been performed for a seat system weight of 272 pounds with an occupant weighting 215 pounds. Loads and reactions for the crash condition are described in Figure 4-70 and Table 4-15. Forward, downward, and side components of load are applied individually and in combination at the CG of the occupant and seat system. Internal loads are described in Table 4-16.

The ejection airloads and rocket thrust loads (Figure 4-71) are computed for 687 KEAS, and correspond to an ultimate dynamic pressure of 1600 psf. The ejection airloads as defined by MIL-S-9479B (USAF) were not considered

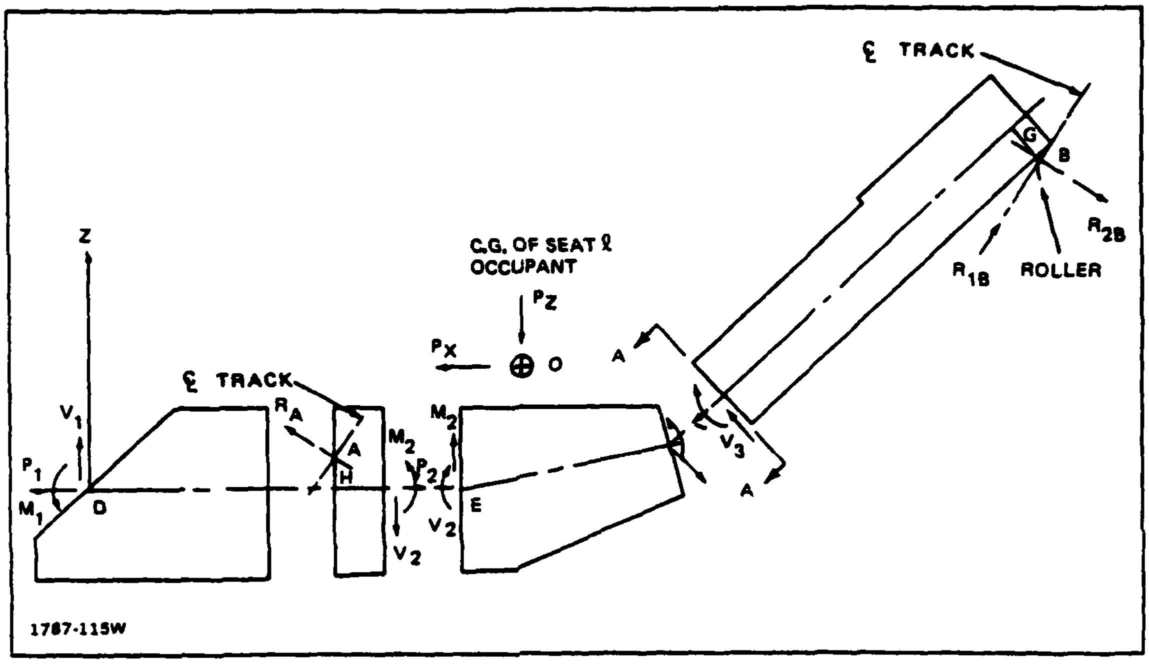


Figure 4-70. Crash Condition Loads

TABLE 4-15. ULTIMATE CRASH LOADS, LB

CONDITION	1	2	3	4 1 & 2	5 1 & 3	6 2 & 3	7 1 & 2 & 3
P_X	0	19480	0	19480	0	19480	19480
P_Y	0	0	6663	0	6663	6663	6663
P_Z	12175	0	0	12175	12175	12175	12175
RA	10207	−6671	0	3536	10207	−6671	3536
RYA	0	0	−4864	0	−4864	−4864	−4864
R1B	10610	9851	0	20461	10610	9851	20461
R2B	3793	10002	0	13796	3793	10002	13795
RYB	0	0	−1799	0	−1799	−1799	−1799
1787-116W							

TABLE 4-16. CRASH CONDITION, ULTIMATE INTERNAL LOADS

CONDITION	1	2	3	4	5	6	7
				1 & 2	1 & 3	2 & 3	1 & 2 & 3
$P_1 = P_2$ (lb)	8839	−5777	0	3062	8839	−5777	3062
$V_1 = V_2$ (lb)	5103	−3336	0	1768	5103	−6671	3536
M_1 (in. − lb)	16331	−10673	0	5658	16331	−10673	5658
V_2 (lb)	6941	−4536	0	2404	6941	−4536	6941
P_2 (lb)	7451	−4870	0	2581	7451	−4870	2581
M_2 (in. − lb)	22455	−14676	0	7779	22455	−14676	7779
V_3 (lb)	3035	9294	0	12329	3035	9294	12329
P_3 (lb)	10986	10529	0	21515	10986	10529	21515
M_3 (in. − lb)	3008	−169471	0	−166463	3008	−169471	−166463
1787-117W							

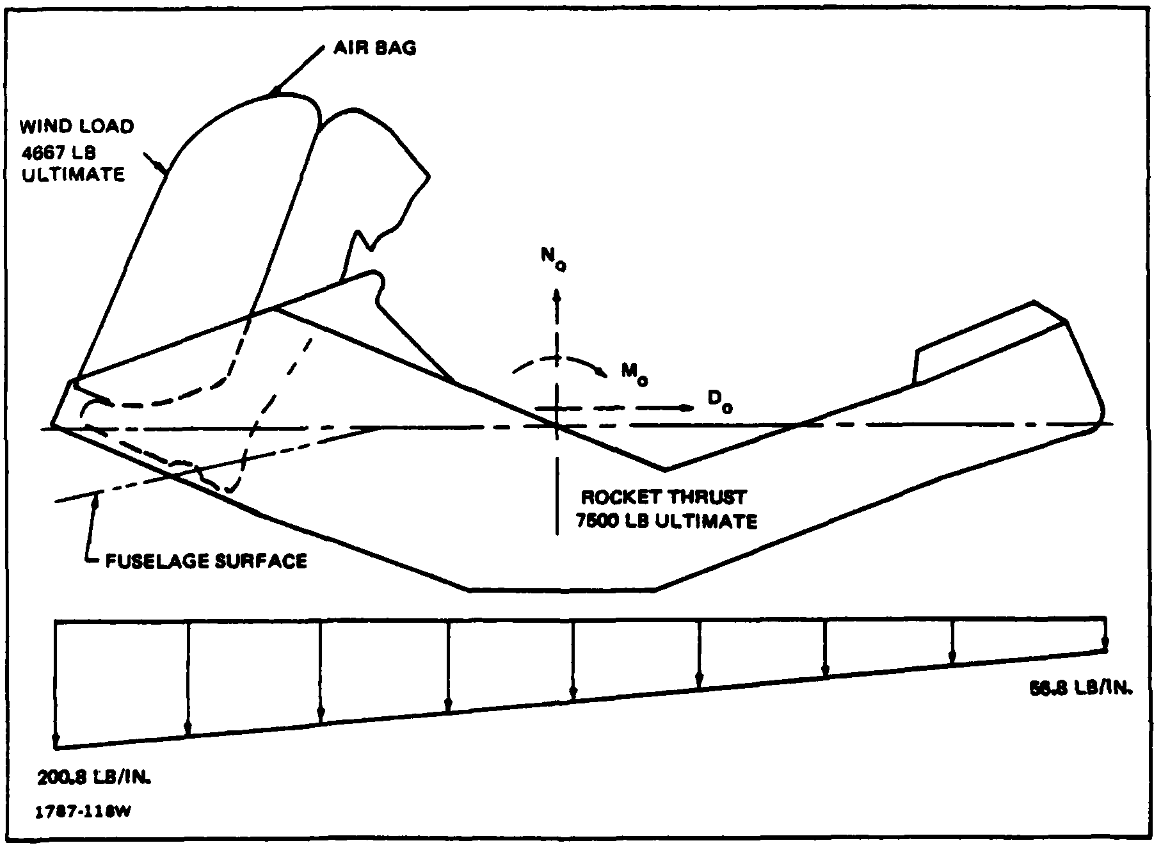


Figure 4-71. Ejection Airload and Rocket Thrust Loads

because of the unique reclining position at ejection. This 4667-pound load is not distributed over the seat back, but rather over the bottom of the seat and protective air bag as exposed to the air stream. These loads are combined with an ultimate rocket thrust of 7500 pounds. Figure 4-71 shows how the resulting normal load and moments about the CG of the seat and occupant are reacted as a distributed trapezoidal load, as shown in the figure. The drag is also assumed distributed along the length of the seat. Preliminary analysis indicates that the condition is not critical for the basic seat structure in comparison to the crash load condition, except for the rocket support structure and regions of the seat bottom designed by airload pressures.

The seat structure is subject to maximum bending at Section A-A (Figure 4-70), and has been sized as shown in Figure 4-72 for both the vertical and lateral bending moments which are incurred at the section.

4.6.2.4 Canopy System - The canopy/windshield/instrument panel is a single unit which pivots about a hinge at the forward end for normal ingress/egress

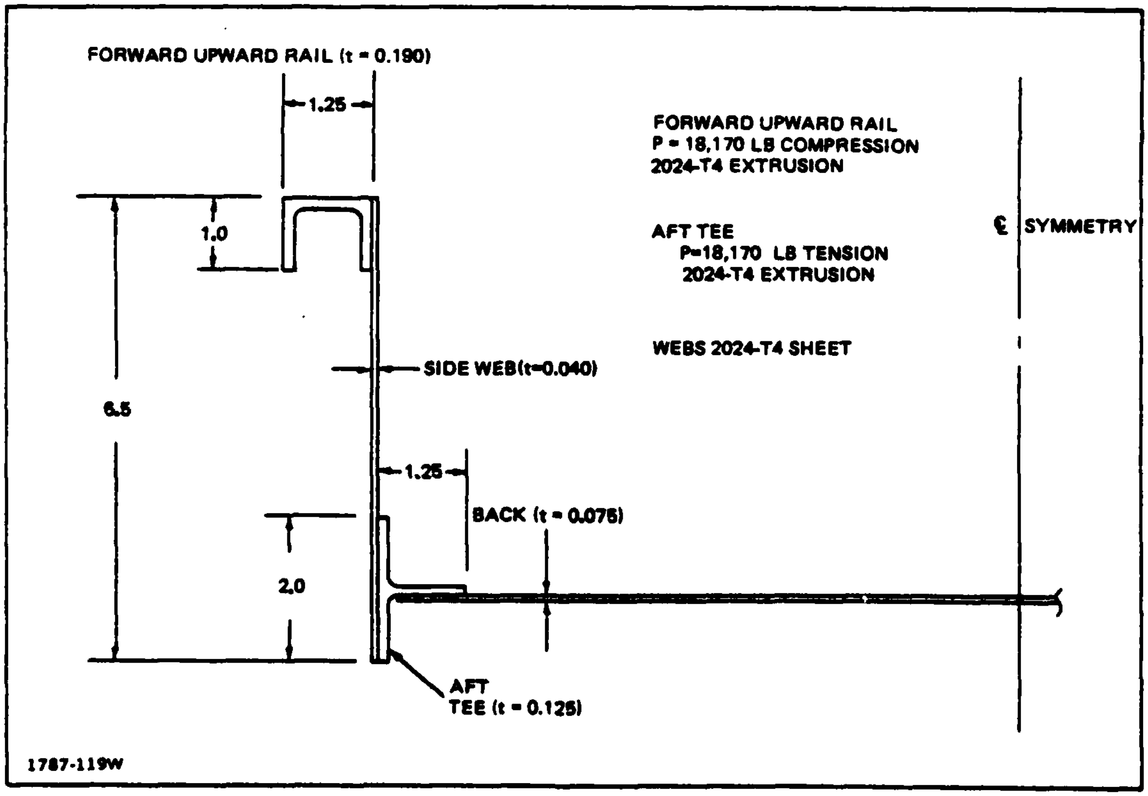


Figure 4-72. Section A-A, Seat Structure

and maintenance. An aircraft/canopy disconnect carries electrical, defog, and ballistic gas lines to the canopy. The pilot enters the aircraft below and aft of the canopy and actuates the "canopy close" switch. The hydraulic actuator lowers the canopy to the sill, engaging the canopy lock pins and two canopy jettison pivot pins at the top of the aft bulkhead.

Canopy jettison is activated by any one of three handles: the escape system initiating handles located in the side panels of the seat, the interior canopy jettison handle located at the forward end of the R.H. side console, or the exterior canopy jettison handles located on each side of the aircraft behind quick access panels. The operation of one of the jettison handles activates a gas generator which supplies pressure to release the forward hinge pins and initiates the firing of the canopy rocket thrusters.

V. AIR VEHICLE APPLICATIONS

The primary objective of this investigation was the evaluation of MSLPC escape system concepts and MSLPC fighter applications. The MSLPC baseline configuration is applied to several fighter aircraft configurations for an evaluation which identifies and quantifies (where possible) the benefits in terms of reduced aircraft size, drag, signature, complexity, weight, and cost.

5.1 CANDIDATE CONFIGURATIONS

The baseline air vehicles for the MSLPC integration were derived from the fighter and penetrator configurations associated with the Configuration Development of Advanced Fighters (CDAF) program. The aircraft are twin engined, canard/wing configurations with single place cockpits. The MSLPC baseline aircraft were evaluated with and without the CDAF radar antenna in order to measure unconstrained MSLPC benefits.

5.1.1 Air Vehicle Design

The cockpit envelope in all fighter aircraft configurations is constrained by exterior vision, sensor, and armament requirements. The application of MSLPC to the baseline vehicles has a pronounced effect on exterior vision with respect to the longitudinal aerodynamic control surfaces. Both vehicles are canard configured to take advantage of the enhanced agility capability that advanced Automatic Flight Control System and Fly By Wire state-of-the-art (AFCS/FBW) offer with Relaxed Static Stability (RSS). With the wing-body configuration neutrally stable, the canard size and its distance from the CG (canard stability "volume" contribution) has to be adjusted for the proper instability level for safe transonic agility and for supersonic cruise neutral trim. The canard moment arm is constrained with respect to the minimum length necessary to avoid excessive canard size (large wetted area and excessive interference with wing lift distribution-tandem wing effect), deflections, and/or canard wing overlap (canard deflection interference). Thus the exposed

canard is usually sized at about 15 to 20% of the total reference area and located 1.25 to 1.50 Mean Aerodynamic Chord (MAC) lengths of the wing from canard Center-of-Pressure (CP) to aircraft Center-of-Gravity (CG). With the relatively large wings demanded by high g maneuver requirements combined with low aspect ratio for supersonic cruise, the mean aerodynamic chords are quite large and the canards are thus driven forward along the fuselage in compliance with the above canard size/location stipulation.

In addition, vertical canard placement with respect to the wing for beneficial mutual interference, and good directional stability maintenance with canard deflection at high angles of attack, dictates that the canards be inplane or slightly above the wing chord plane. Furthermore, vertical canard placement is configuration dependent as described in the following subsections.

5.1.1.1 Fighter Configuration - The aircraft shown in Figure 5-1 reflects a canard located slightly above the wing chord plane to provide gun barrel passage. The forward placement of the canard above the wing plane is combined with as small a forward fuselage or canopy height as possible for minimum wave drag. A large, steep, cross-sectional area progression not only contributes large wave drag by itself, but interferes with the attainment of an optimal Sears-Haack area distribution along the body length, and contributes to even greater wave drag. The location of the canard presents a requirement for locating the cockpit as far forward as possible to avoid extensive masking of vision by the canard on the low rear quarter. The MSLPC, with its reduced height, can be translated further forward than conventional cockpits before the floor coincides with the bottom of the nose section envelope. Development of fire control avionics that can be disassociated from the immediate proximity to the radar antenna is essential to the provision of necessary vision and lowest possible supersonic wave drag.

5.1.1.2 Penetrator Configuration - In addition to the design features of the above fighter configuration, the penetrator shown in Figure 5-2 also satisfied a requirement to carry air-to-ground weapons internally and in tandem. To avoid installed weapon friction and interference drag, and comply with internal volume/wave drag requirements, the two engines were separated and semi-podded below and outboard of the wing roots. To avoid possible canard wake ingestion by the engine inlets, the canard was

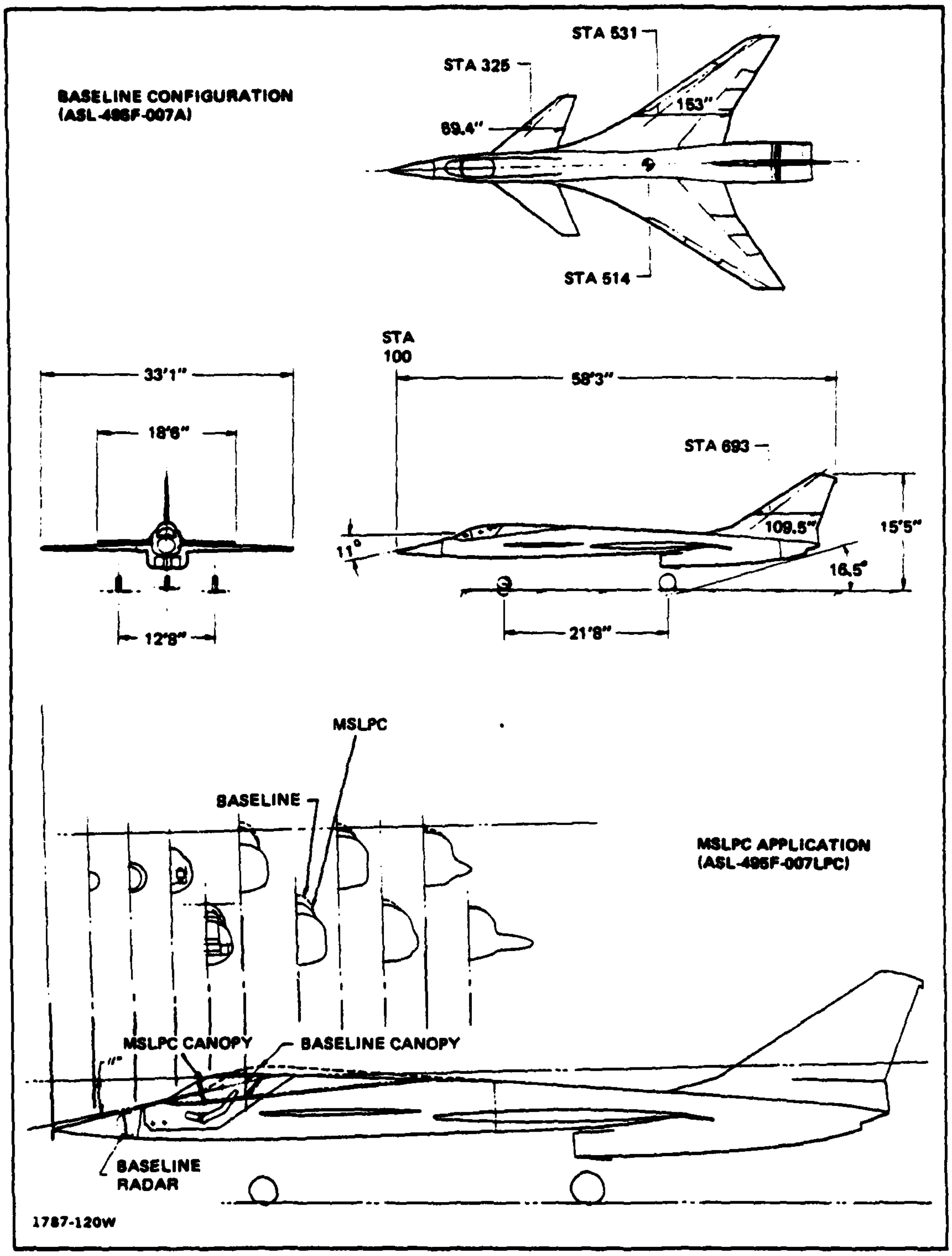


Figure 5-1. Mach 1.6 Fighter

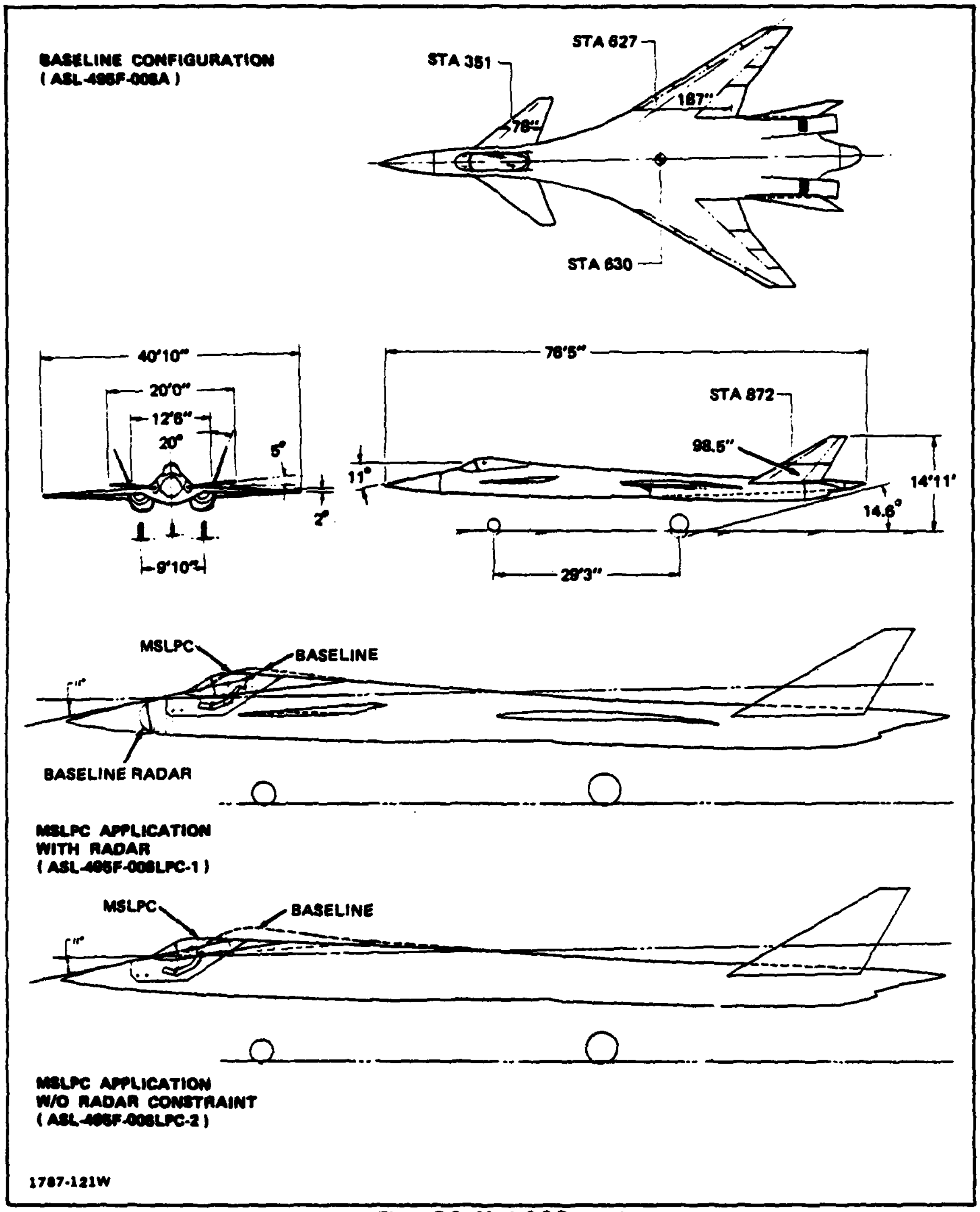


Figure 5-2. Mach 2.0 Penetrator

located slightly above that of the fighter based on the wind tunnel flow wake surveys of Ref. 6.

The larger radar antenna on the penetrator permits the MSLPC to be translated forward with respect to canard/vision/gun integration without impacting the installation of the fire control avionics adjacent to the antenna below the cockpit.

5.1.1.3 Penetrator Configuration Without Radar - Without the radar antenna and associated fire control avionics, the MSLPC can be translated forward until the lower forward corners of the cockpit envelope contact the lower nose section contours. The lower hemisphere of the nose section is unchanged to retain a sensible-length bullet trough and trajectory clearance. The canard location and deflection-range "scrubbing" surface also remains unchanged. The upper hemisphere of the nose section is modified to accommodate the forward location of the cockpit which blends into the basic fuselage contours more quickly.

With its reduced height and more rapid blending, the cockpit in this location reduces the wetted area and, when combined with the canard, a smoother local integrated area distribution is obtained which reduces supersonic wave drag.

5.2 EFFECTS ON AIR VEHICLE SIZE

The MSLPC is applied to the candidate fighter aircraft configurations to determine attendant effectiveness benefits. Given the baseline aircraft performance envelope, air vehicle size benefits are derived in terms of drag, wetted area, and take-off gross weight. The CISE computer program is used to implement the derivation. Mission profiles and output data are included in Appendix E.

5.2.1 Aircraft Characteristics

The application of MSLPC to the baseline fighter (Figure 5-1) and baseline penetrator (Figure 5-2) was evaluated on the basis of the existing CDAF mission profile (Appendix E). The aerodynamic affects are manifest in two aircraft characteristics: minimum drag coefficient ($C_{D_{min}}$) and directional stability (C_{n_β}). The revised canopy/fuselage lines result in a reduced height and canopy/fuselage side area yielding a more directionally stable vehicle. This allows a reduction in vertical tail area while maintaining the directional stability level of the baseline vehicle.

The reduced tail area and the MSLPC associated area distribution for the fighter (Figure 5-3) and penetrator (Figure 5-4) provide a reduction of configuration wave drag and fuselage wetted area. Since the wing characteristics (aspect ratio Δ, λ, and t/c) are unchanged and the area is essentially photographically changed, the induced drag-due-to-lift and longitudinal stability do not change relative to the baseline configurations.

The integrated area plots are representative of the average area distribution determined by a series of planes intersecting the vehicle longitudinal axis at the Mach angle, and does not necessarily reflect the normal cross sectional area distribution. As seen in Figure 5-5, the expanded scale for the region between Fuselage Stations 185 and 280 illustrates that only at Mach 1.0, where the Mach planes are normal to the longitudinal axis, does the integrated area distribution reflect exactly the normal cross sectional area distribution.

5.2.2 Summary of Cumulative Effects

The incremental MSLPC effects on the fighter, penetrator with radar, and penetrator without radar configurations are summarized in Table 5-1 in terms of the un-iterated aerodynamic effects and the fully iterated CISE parametric vehicle definition.

The subsonic difference in drag levels between the MSLPC and baseline fighter configurations is a result of the change in friction drag and wetted area. The supersonic drag level of the MSLPC fighter reflects the reduction in wave drag associated with the improved area diagram. The directional stability level of the baseline fighter configuration served as the limit for the reduction of tail area made possible by the more stable MSLPC wing-body level. The subsonic stability level was matched, the transonic level was slightly compromised, and the supersonic level was improved.

The difference in drag levels between the MSLPC and baseline penetrator configurations is consistent with fighter configuration results, as reflected in the wetted area developed with and without a radar constraint. The directional stability level of both MSLPC penetrators match the baseline level subsonically. The configuration without radar constraint has the greater reduction in tail size which does compromise

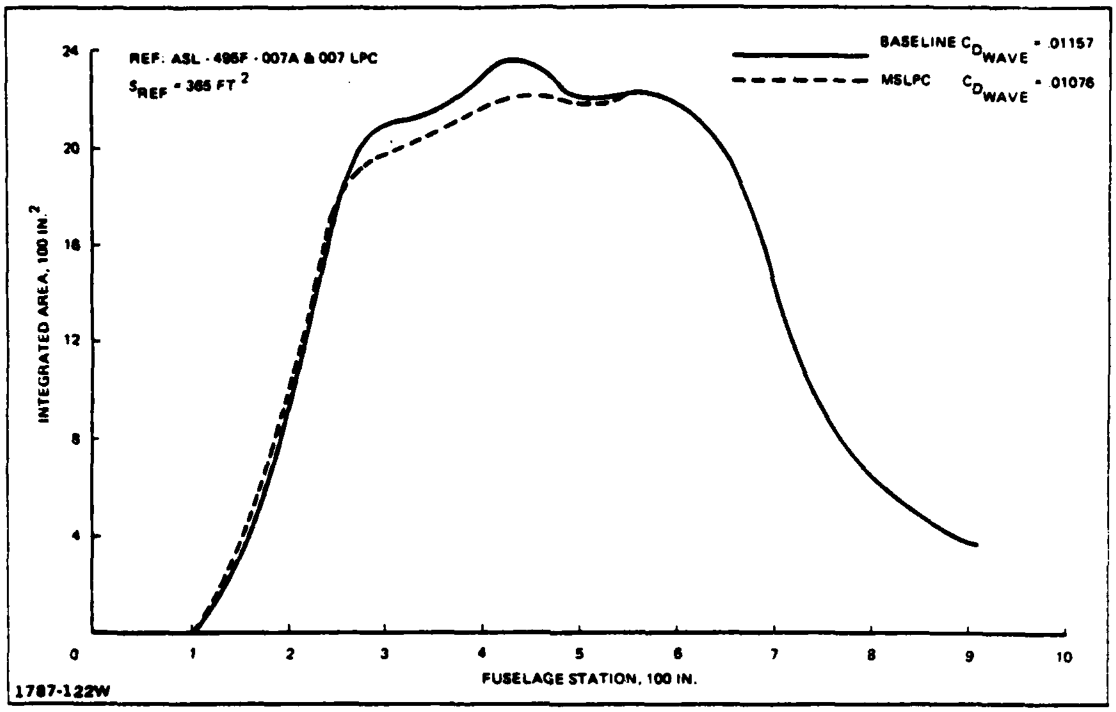


Figure 5-3. Integrated Area Curve, M 1.6 Fighter

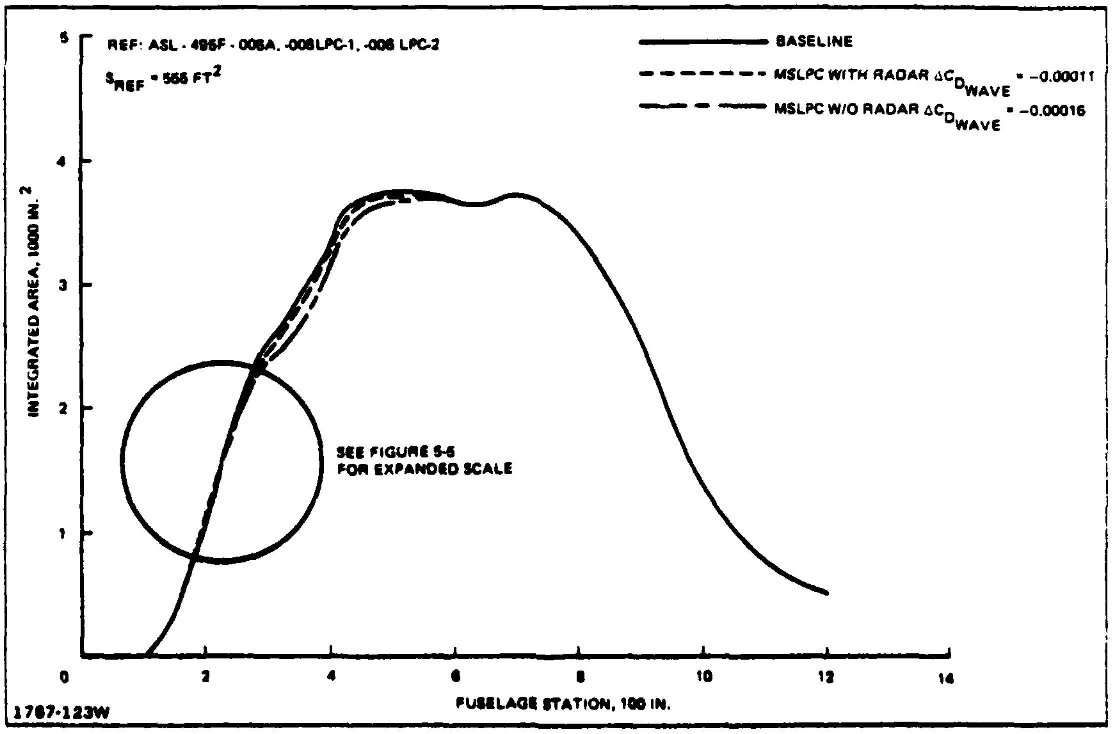


Figure 5-4. Integrated Area Curve, M 2.0 Penetration

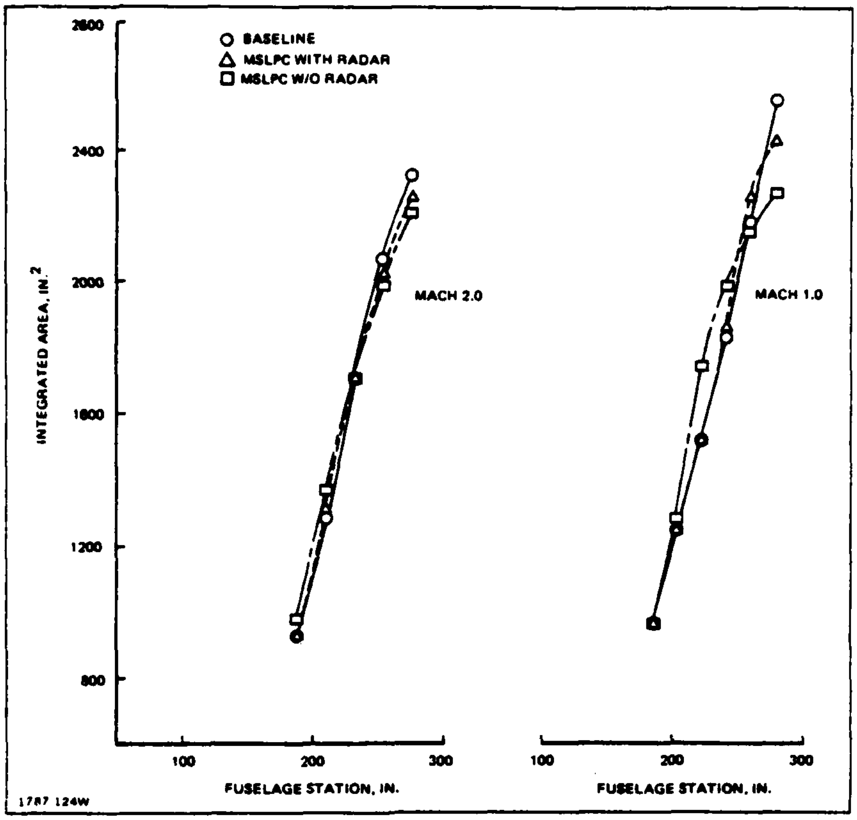


Figure 5-5. Localized Mach Number Effects

TABLE 5-1. DELTA MSLPC EFFECTS

	PARAMETER	FIGHTER (MACH 1.6) ASL-495F-007A	PENETRATOR (MACH 2.0) ASL-495F-006A WITH RAD ANT.	PENETRATOR (MACH 2.0) ASL-495F-006A W/O RAD ANT.
UN-ITERATED INCREMENTAL EFFECTS	SIDE AREA, FT^2	−3.3	−2.0	−9.1
	C_{N_β}, DEG^{-1}	+0.00014	+0.00016	+0.00046
	VERT TAIL AREA, FT^2	−2.5 (3.6%)	−4.7 (4.3%)	−13.6 (12.4%)
	C_D WAVE, COUNTS	−8.1	−1.1	−1.6
	FUSELAGE WETTED AREA, FT^2	−8.9	−4.1	−12.7
PARAMETRIC "CISE" VEHICLE	TOTAL WETTED AREA, FT^2	−27	−34	−72
	EMPTY WEIGHT, LB	−259	−222	−432
	FUEL WEIGHT, LB	−236	−245	−418
	TOGW, LB	−495	−470	−856
1787-125W				

the transonic stability level to a greater degree than the configuration with radar constraint. Conversely, the supersonic level is enhanced to a greater degree.

5.2.3 Escape Concept Effects

Subsequent to resizing the baseline aircraft as a result of the MSLPC application, further iteration was required to determine the effect of escape concept variations on the MSLPC aircraft configuration. Using the CISE inputs presented in Weight and Mass Properties, Subsection 3.4, each escape concept was applied to each MSLPC aircraft configuration. The results, measured in terms of TOGW, are summarized in Table 5-2; output data are included in Appendix E.

5.3 OBSERVABLE SIGNATURES

Aircraft observables, such as radar cross section, infrared, and visual/electro optical signatures, enhance the ability to detect and locate. In the evaluation of MSLPC applications it was assumed that all aircraft would be treated with radar cross section signature reduction suits in order to accentuate the effect of MSLPC. Measurement of cockpit radar signatures with respect to frontal RCS (Figure 5-6) indicate a 0.49 m^2 MSLPC fighter versus a 0.54 m^2 baseline fighter, and a 0.93 m^2 MSLPC penetrator versus a 1.0 m^2 baseline penetrator. The infrared signature produced by plume exhaust gases and hot metal emissions is not significantly reduced in the MSLPC fighter

TABLE 5-2. AIR VEHICLE TOGW SUMMARY

VEHICLE CONFIGURATION	TAKEOFF GROSS WEIGHT, LB		
	FIGHTER	PENETRATOR WITH RADAR CONSTRAINT	PENETRATOR W/O RADAR CONSTRAINT
BASELINE	24128	41225	41225
MSLPC APPLICATION	23630	40755	40369
DEFLECTION WEDGE	23690	40826	40440
TRACTOR ROCKET	23598	40718	40333
CURVED TRACK	23578	40695	40309
SHIELD/CANOPY	23599	40720	40333
"B" SEAT VARIANT	23637	40763	40376
SUPINE CONCEPT	23598	40695	40309
1787-126W			

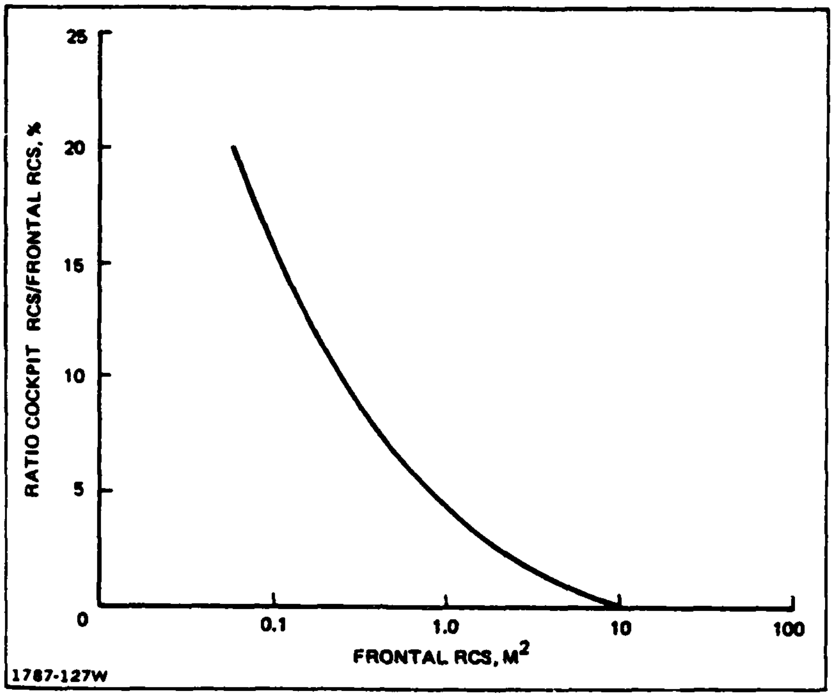


Figure 5-6. Effect of Cockpit RCS on Frontal RCS

and penetrator. Key factors in determining sensitivity to optical detection are canopy glint, exhaust (smoke/contrails), and aircraft size. Canopy glint will remain a constant since no attempt to incorporate flat panel transparencies was undertaken. Exhaust detection cues such as smoke or contrails are not affected by cockpit selection. The application of MSLPC results in a reduction of 1.8% in the size of the fighter, and 2.4% in size of the penetrator, when measured in terms of total projected area.

5.4 VULNERABILITY

The MSLPC can facilitate a small (2 to 3%) reduction in combat vulnerability in each of the baseline aircraft. The smaller frontal area obtained by incorporating the MSLPC allows the aircraft to be downsized, thereby diminishing the exposed area of two prime contributors to combat vulnerability - the fuel system and the flight control system. Vulnerability of the pilot within the cockpit envelope appears to be unchanged by the MSLPC compared to the baseline. Assuming that a shot penetrating the pressure envelope of the cockpit will result in spall, the difference is measured in terms of cockpit area rather than pilot body area. The reduced exposure of the cockpit to shots from the side is balanced by the increased exposure to shots from the top and

bottom. Shots from the front or rear, though against a reduced area, are of little import because of the protection afforded by structure and equipment along these paths.

The effect of MSLPC on combat vulnerability was evaluated for both the fighter and penetrator derivatives of the CDAF design reference. The procedure used for this evaluation is shown in flow chart format in Figure 5-7. The basis of this procedure is a correlation observed among combat loss experience, the causes of loss, and measurable characteristics of the aircraft lost. Application of this procedure to the fighter is shown in Table 5-3, and to the penetrator in Table 5-4. The measure which is significant is the ratio of change induced to the baseline loss rate. Note that this absolute value of the loss rates developed by this procedure reflect past conflicts and should not be applied directly to future situations without adjustment for scenario and threat level. These benefits are obtained only if the aircraft are resized, not simply by exchange of cockpit designs within the same size aircraft. The MSLPC penetrator with radar constraint was not evaluated in view of the very small benefit found for the MSLPC penetrator without radar constraint.

5.4.1 Combat Loss Rate

The combat vulnerability estimation procedure used to evaluate the MSLPC is based on data extracted from SE Asia combat experience. The combat loss rates (losses per sortie) for a number of aircraft models were found to be usefully correlated

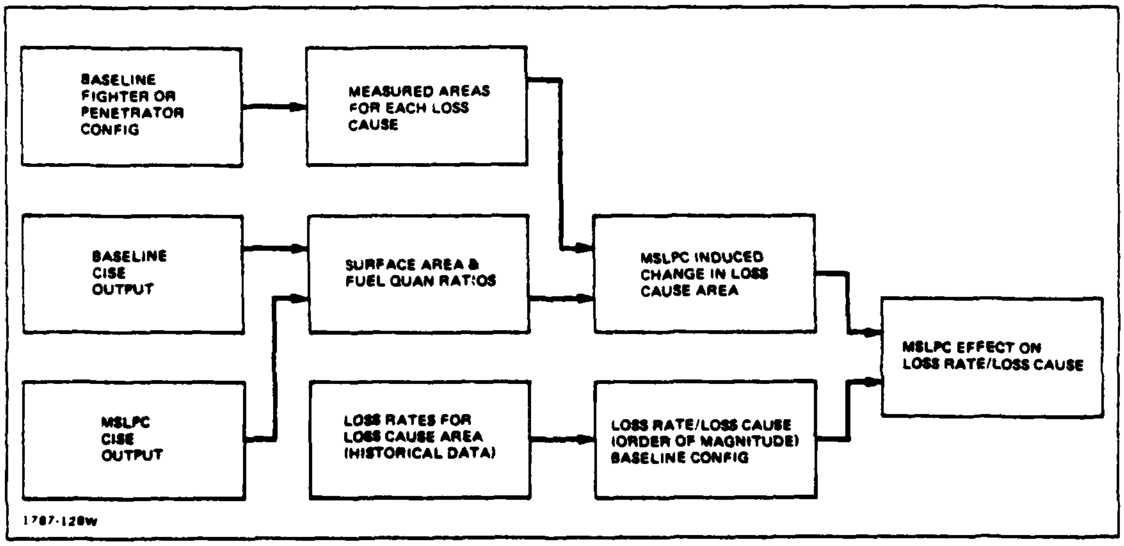


Figure 5-7. Combat Vulnerability Assessment Procedure

TABLE 5-3. EFFECT OF MSLPC ON FIGHTER VULNERABILITY

LOSS CAUSE	SCALING CISE DATA		LOSS CAUSE AREA, FT^2		COMBAT LOSS RATE, PER 10,000	
	FIGHTER BASELINE	MSLPC FIGHTER	FIGHTER BASELINE	MSLPC FIGHTER	FIGHTER BASELINE	MSLPC FIGHTER
PILOT INCAPACITATION	–	–	21	NOTE 1	2.3	NEGLIGIBLE
FIRE INTENSITY FUSELAGE FUEL RATIO	$(\text{FUEL QUAN. RATIO})^{2/3}$ 3332 / 0.96	3215	72	–2.9	5.0	-0.26
EXPLOSION WING FUEL RATIO	$(\text{FUEL QUAN. RATIO})^{2/3}$ 3332 / 0.96	3215	72	–2.9	0.2	NEGLIGIBLE
ENGINE FAILURE	IGNORED - SMALL ABSOLUTE VALUE IN TWIN ENGINE AIRCRAFT				0.1	NEGLIGIBLE
LOSS OF CONTROL PARTIAL PLAN AREA RATIO	(PLAN AREA RATIO) 650 / 0.992	645	431	–3.5	0.8	NEGLIGIBLE
MISC (INCL AMMO)	NOT EVALUATED - NO COCKPIT EFFECTS EXPECTED; ESTIMATED AS				1.0	0
			CUMULATIVE COMBAT LOSS RATE		9.4	–0.26

NOTE 1 - THE MSLPC DOES NOT IN ITSELF SIGNIFICANTLY ALTER THE VULNERABILITY OF THE PILOT

1787-129W

TABLE 5-4. EFFECT OF MSLPC ON PENETRATOR VULNERABILITY

LOSS CAUSE	SCALING CISE DATA		LOSS CAUSE AREA, FT^2		COMBAT LOSS RATE, PER 10,000	
	PENETRATOR BASELINE	MSLPC PENETRATOR	PENETRATOR BASELINE	MSLPC PENETRATOR	PENETRATOR BASELINE	MSLPC PENETRATOR
PILOT INCAPACITATION	–	–	21	*	2.3	NEGLIGIBLE
FIRE INTENSITY FUSELAGE FUEL RATIO	$(\text{FUEL QUAN RATIO})^{2/3}$ 6910 / 0.98	6702	174	–3.5	14.0	–0.32
EXPLOSION WING FUEL RATIO	$(\text{FUEL QUAN RATIO})^{2/3}$ 6910 / 0.98	6702	174	–3.5	2.3	–0.1
ENGINE FAILURE	IGNORED - SMALL ABSOLUTE VALUE IN TWIN ENGINE AIRCRAFT				0.1	NEGLIGIBLE
LOSS OF CONTROL PARTIAL PLAN AREA RATIO	(PLAN AREA RATIO) 1000 / 0.96	960	738	–29.5	1.3	0.05
MISC (INCL AMMO)	NOT EVALUATED - NO COCKPIT EFFECTS EXPECTED; ESTIMATED AS				1.0	0
			CUMULATIVE COMBAT LOSS RATE		21.0	–0.47

* THE MSLPC DOES NOT IN ITSELF SIGNIFICANTLY ALTER THE VULNERABILITY OF THE PILOT

1787-130W

to measurable features of each aircraft and the generic causes of loss identifiable with these features as shown in Figure 5-8. The loss causes of greatest import are pilot incapacitation, fire, explosion, loss of control, and engine failure. A miscellaneous category was used to collect other features including the gun ammunition.

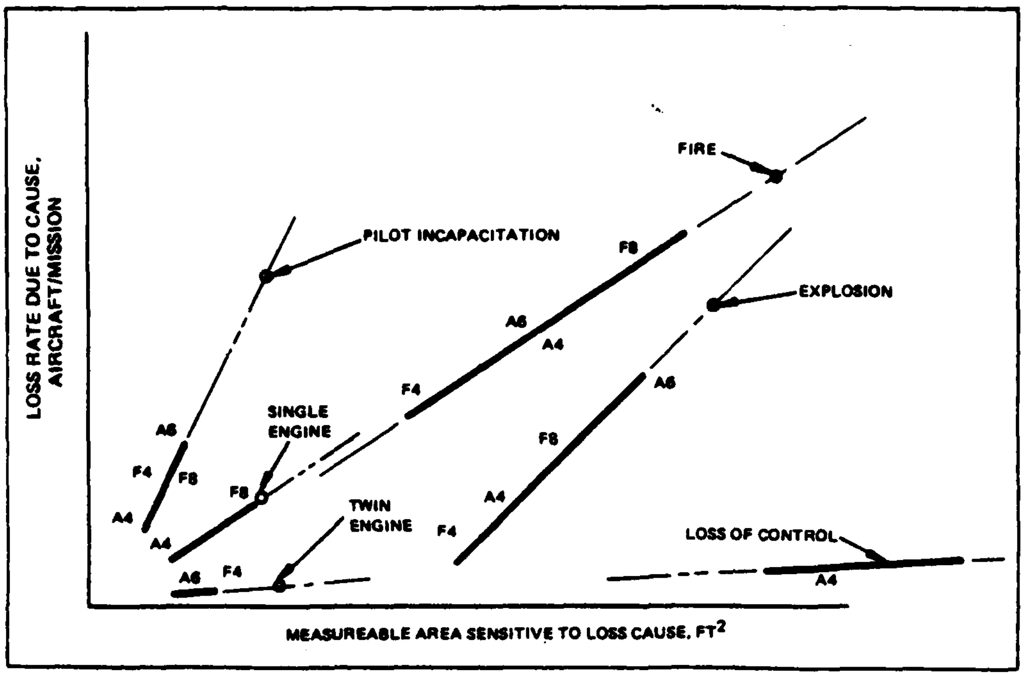


Figure 5-8. Combat Loss Rates and Causes

5.5 LIFE CYCLE COST

In order to evaluate cost as part of the analysis to identify the preferred MSLPC concepts, the Modular Life Cycle Cost Model (MLCCM) was used (Ref. 5). This model was developed by Grumman under contract to the Air Force for use by designers to make parametric trade studies. It is sensitive to design parameters down to subsystem level and permits the life cycle cost (LCC) evaluation of aircraft configurations from design through the support phase.

Using the configuration definition for the baseline fighter and penetrator as shown in the CISE runs (Appendix E), the required input parameters were derived and the MLCCM was run. The model output results represent a typical procurement of 500 vehicles over a life of 15 years, and form the baseline for the delta costs resulting from the application of the MSLPC concepts to the fighter and penetrator configurations. The MLCCM output data is included in Appendix D.

5.5.1 Vehicle Configurations

The configuration changes which resulted from the integration of the MSLPC and the crew escape system concepts were iterated through the CISE program, and the results were evaluated for cost using the MLCCM program. The changes in cost

driving parameters were identified, and the impact of the MSLPC concepts on the baseline vehicles resulted in the vehicle cost differences shown in Tables 5-5, 5-6, and 5-7.

5.5.2 Crew Systems

Until more definitive studies are made of the MSLPC seat, pyrotechnics, and other required components, no detail cost analysis of the escape system itself can be done. Since this cost represents approximately 2% of the total LCC, the effect on the results of this analysis is negligible. The LCC analysis assumes cost of these components to be similar to conventional escape system hardware. The output results of the MLCCM for the crew systems costs are given in Appendix D, and are based on sensitivity to the input parameters shown.

5.5.3 Conclusions

Five MSLPC escape system concepts were evaluated: curved track, tractor rocket, shield/canopy, "B" seat variant, and deflection wedge. All escape concepts showed savings from the baseline vehicles as shown in Tables 5-5, 5-6, and 5-7. The impact each of the concepts had on the fighter and the penetrator basic MSLPC vehicle LCC is shown in Figure 5-9. The magnitude of the delta cost for each concept over the life cycle for a typical procurement of 500 vehicles with a life of 15 years is delineated. The escape concepts which showed savings from the basic MSLPC vehicles were the curved track, the tractor rocket, and the shield/canopy. The "B" variant concept was close to the basic MSLPC, while the deflection wedge was costlier.

TABLE 5-5. FIGHTER LIFE CYCLE COST, ($M 1979, Excluding Engines and Avionics)

CONFIGURATION	RDT&E, 2 A/C	PROD, TOTAL 500	INITIAL SUPPORT	OPER & SUPPORT	TOTAL LCC
BASELINE	391.853	2415.575	237.474	3464.353	6509.255
MSLPC	383.243	2390.486	236.428	3460.297	6470.454
CURVED TRACK	382.552	2387.161	236.350	3459.429	6465.492
TRACTOR RKT	382.881	2389.416	236.388	3459.773	6468.458
SHIELD CANOPY	382.884	2389.423	236.388	3459.793	6468.488
"B" VARIANT	383.519	2390.528	236.460	3460.452	6470.959
DEFL WEDGE	384.215	2394.274	236.538	3461.807	6476.834
DELTA COST IMPACT OF MSLPC ON FIGHTER BASELINE					
CONFIGURATION	Δ RDT&E	Δ PRODUCTION	Δ INIT SUPP	Δ O&S	Δ LCC
MSLPC	−8.610	−25.089	−1.046	−4.056	−38.801
DELTA COST IMPACT OF ESCAPE FACTORS ON FIGHTER MSLPC					
CONFIGURATION	Δ RDT&E	Δ PRODUCTION	Δ INIT SUPP	Δ O&S	Δ LCC
CURVED TRACK	−0.691	−3.325	−0.078	−0.868	−4.962
TRACTOR RKT	−0.362	−1.070	−0.040	−0.524	−1.996
SHIELD CANOPY	−0.359	−1.063	−0.040	−0.504	−1.966
"B" VARIANT	+0.276	+0.042	+0.032	+0.155	+0.505
DEFL WEDGE	+0.972	+3.788	+0.110	+1.510	+6.380
1787-132W					

TABLE 5-6 PENETRATOR LIFE CYCLE COST WITH RADAR, ($M 1979, Excluding Engines and Avionics)

CONFIGURATION	RDT&E, 2 A/C	PROD, TOTAL 500	INITIAL SUPPORT	OPER & SUPPORT	TOTAL LCC
BASELINE	750.502	3274.137	306.375	4393.403	8723.417
MSLPC	737.266	3242.469	303.549	4386.811	8670.095
CURVED TRACK	736.041	3238.493	303.384	4385.160	8663.078
TRACTOR RKT	736.805	3241.600	303.487	4385.559	8667.451
SHIELD CANOPY	736.811	3241.607	303.487	4385.590	8667.495
"B" VARIANT	737.626	3241.806	303.597	4386.291	8669.320
DEFL WEDGE	738.529	3246.486	303.717	4388.636	8677.368
DELTA COST IMPACT OF MSLPC ON PENETRATOR BASELINE					
CONFIGURATION	Δ RDT&E	Δ PRODUCTION	Δ INIT SUPP	Δ O&S	Δ LCC
MSLPC	−13.236	−31.668	−1.826	−6.592	−53.322
DELTA COST IMPACT OF ESCAPE FACTORS ON PENETRATOR MSLPC WITH RADAR					
CONFIGURATION	Δ RDT&E	Δ PRODUCTION	Δ INIT SUPP	Δ O&S	Δ LCC
CURVED TRACK	−1.225	−3.976	−0.166	−1.651	−7.017
TRACTOR RKT	−0.461	−0.869	−0.062	−1.252	−2.644
SHIELD CANOPY	−0.455	−0.862	−0.062	−1.221	−2.600
"B" VARIANT	+0.360	−0.663	+0.048	−0.520	−0.775
DEFL WEDGE	+1.263	+4.017	+0.168	+1.825	+7.273
1787-133W					

TABLE 5-7 PENETRATOR LIFE CYCLE COST WITHOUT RADAR ($M 1979, Excluding Engines and Avionics)

CONFIGURATION	RDT&E, 2 A/C	PROD, TOTAL 500	INITIAL SUPPORT	OPER & SUPPORT	TOTAL LCC
BASELINE	750.502	3274.137	305.375	4393.403	8723.417
MSLPC	722.669	3209.100	301.549	4381.917	8615.235
CURVED TRACK	721.438	3204.406	301.384	4380.932	8608.160
TRACTOR RKT	721.863	3206.724	301.440	4381.324	8611.351
SHIELD CANOPY	721.863	3206.724	301.440	4381.324	8611.351
"B" VARIANT	722.692	3209.129	301.551	4382.034	8615.406
DEFL WEDGE	723.912	3212.404	301.715	4384.415	8622.446
DELTA COST IMPACT OF MSLPC ON PENETRATOR BASELINE					
CONFIGURATION	Δ RDT&E	Δ PRODUCTION	Δ INIT SUPP	Δ O&S	Δ LCC
MSLPC	−27.833	−65.037	−3.826	−11.486	−108.182
DELTA COST IMPACT OF ESCAPE FACTORS ON PENETRATOR MSLPC W/O RADAR					
CONFIGURATION	Δ RDT&E	Δ PRODUCTION	Δ INIT SUPP	Δ O&S	Δ LCC
CURVED TRACK	−1.231	−4.694	−0.165	−0.985	−7.075
TRACTOR RKT	−0.806	−2.376	−0.109	−0.593	−3.884
SHIELD CANOPY	−0.806	−2.376	−0.109	−0.593	−3.884
"B" VARIANT	+0.023	+0.029	+0.002	+0.117	+0.171
DEFL WEDGE	+1.243	+3.304	+0.166	+2.498	+7.211
1787-134W					

The implementation of the basic MSLPC concept can result in a LCC savings of $38M (0.59%) to a fighter program, $53M (0.61%) to a penetrator with radar constraint, and $108M (1.24%) to a penetrator without radar constraint requirement. Further, if the curved track concept is applied, additional LCC savings in the order of $5M to $7M can be realized. Although these dollar values are not meant to be absolute, they do represent the order of magnitude and relative direction of savings possible when MSLPC concepts are applied.

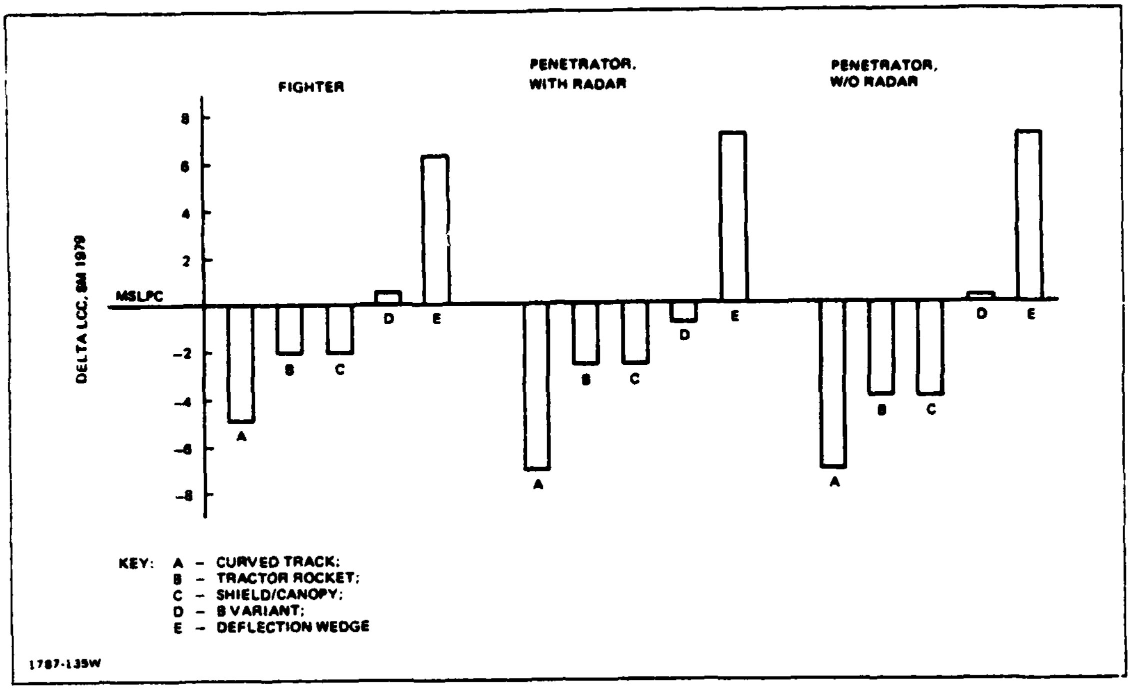


Figure 5-9. Delta Cost Impact of Escape Factors on LCC of MSLPC Vehicle

VI. IDENTIFICATION OF FUTURE EFFORT

Major improvements in crew station design and air vehicle integration cannot be accomplished without injection of new technology and design approaches. While the definition and evaluation of the MSLPC and an integrated escape system are the end products of this study, favorable analytical and mockup-confirmed conclusions do not necessarily constitute acceptability. Further development is required to resolve problem areas. A more detailed design and analysis of the concept is necessary to confirm engineering validity. A sequential development effort would be directed at experimentally confirming the characteristics and performance of the system. Austere wind tunnel and RCS measurement programs using available existing models would provide confirmation of the MSLPC benefits to the air vehicle. Simultaneously, simulator experiments would be used to confirm pilot performance during critical phases of the combat mission and improve the man/machine interface. Test of the escape system could then be performed employing a test sled. Ultimately, a flight test program would be conducted for final confirmation of the validity of the MSLPC and integrated escape system.

6.1 CRITICAL PROBLEM AREAS

- Pilot Performance
  - Takeoff and Landing Flight Control
  - Information Display - Content and Format
  - Cockpit Arrangement/Man-Machine Interface
  - Internal and External Visibility
  - Reorientation/Disorientation
- Crew Escape
  - Injury Risk During Launch Sequence
  - Body Restraint, Retraction, Retention During Launch Sequence
  - Free-Flight Characteristics

- Aircraft Integration
  - Launch Clearance Considerations
  - External Visibility - Landing.

6.2 PROBLEM SOLVING EFFORT

Continual development of MSLPC would involve numerous exploratory and fact-finding analyses, simulation, design, and test programs. Some of the important areas of activity to be implemented with respect to a future demonstration program are:

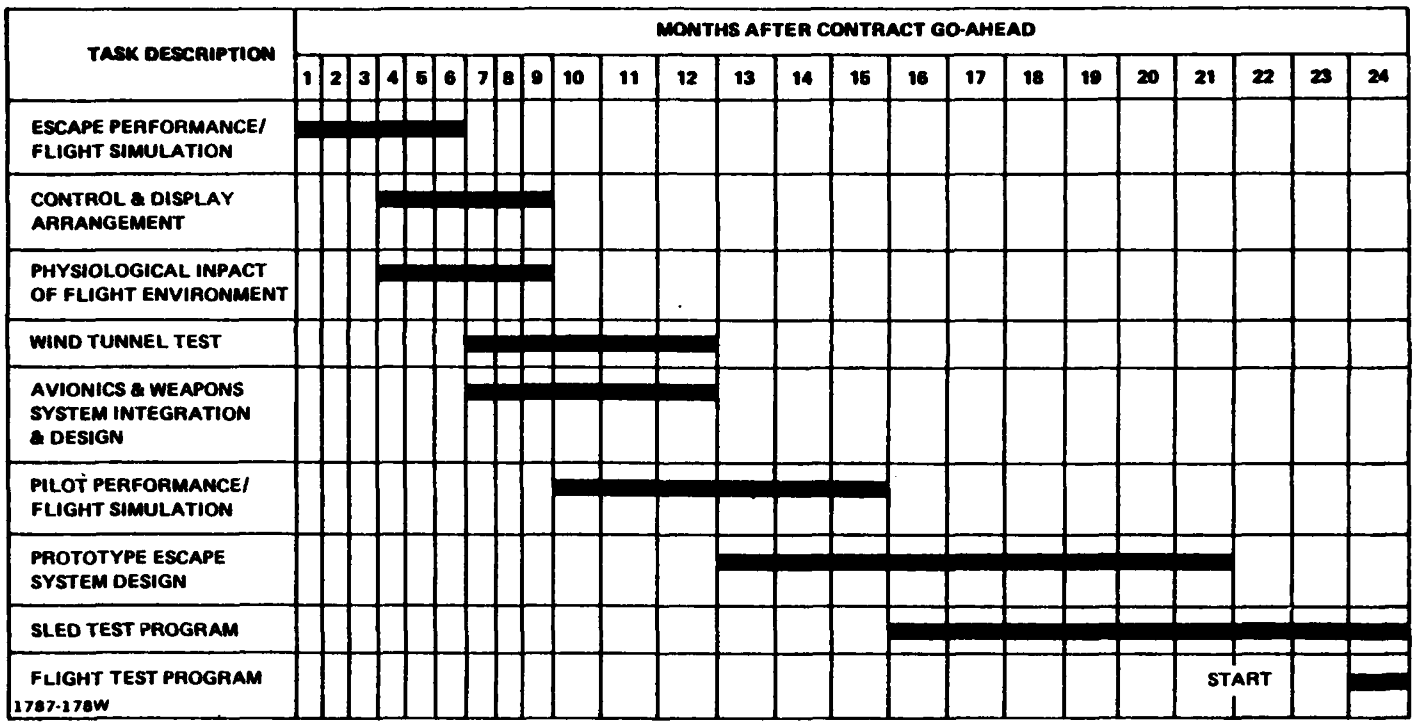
- Develop a plan of action for a wind tunnel program to substantiate the aero performance and aircraft sizing analysis conducted in the MSLPC investigation. The plan should include tunnel testing of the supine seat/man configuration to provide aerodynamic data for performance assessment and design refinement
- Investigate man/machine interface and organize simulator evaluation studies of pilot performance with respect to cockpit information display and control arrangements developed for the MSLPC fixed supine seat configuration; major problem area is the disposition of aircraft subsystem control functions such as environment, lighting, electrical power, communication, and fuel management (control access in the HAC was facilitated by seat articulation)
- Develop a plan of action for the centrifuge and a six-degree of-freedom flight simulator to determine levels of disorientation and the resultant effect on pilot performance
- Extend the investigation of the supine escape system with respect to aerodynamic performance
  - Physiological environment with emphasis on acceleration, wind blast, and limb flail
  - Determine yaw control requirements
  - Develop a detailed definition, integration, and mechanization of the Thrust Vector Control System, Vertical Steering Control System, and Vertical Reference System

- Investigate application and development of expandable fairings, forms, and restraints for escape systems operating at the extreme limits of the free flight performance envelope
- Organize a work effort in observables/signatures to define technologies which offer the greatest potential for MSLPC
- Develop a plan of action for the design, prototype, and sled test for the preferred escape system concept
- Conduct flight tests (subservient to the HAC program activity) to expand the results of the study and define the effects of a fixed 65° geometry through the entire flight profile.

6.3 PLAN OF ACTION

The following plan (Table 6-1) is presented as a frame of reference for establishing work priorities and budget requirements.

TABLE 6-1. WORK SCHEDULE



VII. CONCLUSIONS

- MSLPC baseline geometry provides for an improvement in G tolerance and extends the upward limits of external visibility, but visual access to interior side consoles is degraded. Further investigation of an adjustable headrest/support appears necessary to resolve the specific visibility requirements with respect to external visibility for takeoff/landing conditions and internal visual access to instrument panel/side console surfaces. A closer examination of the physiological constraints and mission requirements is necessary to optimize the seat geometry
- Deflection wedge escape concept has poor potential due to inherent complexity compounded by deployment and stability problems
- Tractor rocket escape concept has poor potential due to inadequate high speed/high G capability
- Shield/Canopy escape concept provides a fine air blast protection capability but has poor potential because of questionable performance in adverse attitude, roll, and spin conditions complicated by the need to separate the crewman from the shield/canopy for the final recovery phase. Active stabilization and attitude positioning are necessary for tail clearance
- "B" Seat Variant escape concept has poor potential due to inherent complexities and time delay for boom deployment
- Curved track escape concept has good potential with a need for further development of limb restraint and containment under crash conditions. Active stabilization is required and attitude positioning is necessary for blast protection. Tradeoffs are possible between thrust oriented (30° forward of vertical) spinal acceleration relief and tail clearance, high speed rocket thrust levels, or trajectory height in low altitude dives

- Supine concept has very good potential. Transverse G (eyeballs-in) are experienced by crewman during separation from aircraft. The escape system is accommodated within the smallest cockpit volume. Some of the apparent complexity would be necessary to satisfy ingress/egress requirements of all concepts. Further development of limb restraint and crash condition containment is required, as well as the investigation of pre-separation cockpit turbulence
- Implementation of active stabilization for extreme performance conditions (high speed, high "q"/adverse attitude, high sink rate) is possible with a blended control system combining the attributes of thrust vector control and vertical steering control. A more specific design philosophy must be established before system optimization can be accomplished
- Application of MSLPC to fighter and penetrator aircraft produces a general improvement of directional stability and a small reduction in wave drag which can be reflected in a smaller (less weight) vehicle.

APPENDIX A

WEIGHT AND BALANCE DATA

For weight and balance purposes a minimum/maximum range of personal equipment weight, representing the crew's clothing and equipment, was established. Table A-1 includes a minimum weight which consists of the 5th percentile crewman's summer clothing and equipment, and a maximum weight which consists of the 95th percentile crewman's winter clothing and equipment.

Tables A-2 through A-6 depict the center of gravity and weight breakdowns and inertia for the five escape system concepts.

TABLE A-1. PERSONAL EQUIPMENT WEIGHT RANGE

ITEM	MIN WT, LB	MAX WT, LB
FLIGHT SUIT	1.81	– (a)
GLOVES	0.36	0.38
HARNESS	4.38	4.38
OXYGEN MASK	1.69	1.69
OXYGEN REGULATOR/HOSE	1.56	1.56
HELMET	3.70	3.90
ANTI-"G" SUIT	2.25	2.25
SURVIVAL VEST	–	12.58 (b)
FLIGHT BOOTS	4.25	4.56
ANTI-EXPOSURE SUIT	–	7.20 (c)
LINER	–	4.70 (d)
TOTALS	20.0	43.20

(a) FLIGHT SUIT WORN ONLY IN SUMMER.
(b) WHEN WORN, EQUIPMENT OPTIONS ARE DICTATED BY SEASONAL AND GEOGRAPHIC CONDITIONS.
(c) EXPOSURE SUIT WORN ONLY IN WINTER.
(d) LINER WORN ONLY IN WINTER.

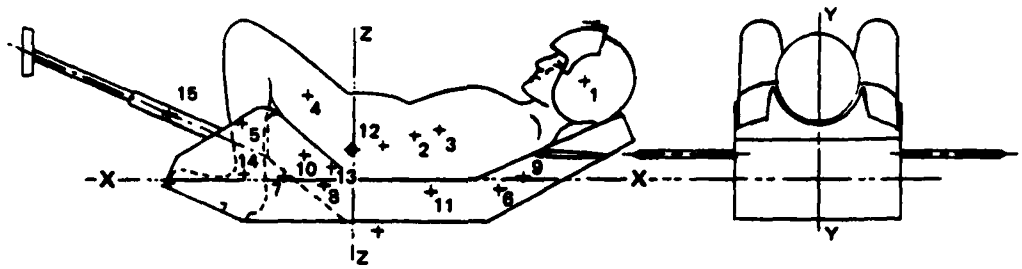
1787-136W

AD-A081 055 GRUMMAN AEROSPACE CORP BETHPAGE NY F/G 1/3
INVESTIGATION OF MINIMUM SIZED LOW-PROFILE COCKPITS (MSLPC) AND--ETC(U)
SEP 79 W C TAUBY F33615-78-C-3427
UNCLASSIFIED AFFDL-TR-79-3104 NL

3 OF 3
AD
A081055

END
DATE
FILMED
3-80
DDC

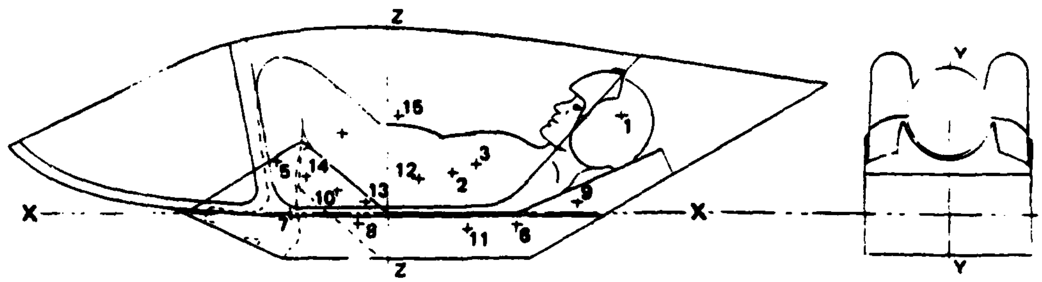
TABLE A-2. ESCAPE SYSTEM CG – DEFLECTION WEDGE CONCEPT
(95th Percentile Pilot)



	WT	X	WX	Z	WZ
1. Head	18.6	28.0	520.8	12.0	223.2
2. Torso	87.4	7.7	672.9	5.4	471.9
3. Arms	27.0	10.4	280.8	5.9	159.3
4. Thighs	46.0	−4.6	−211.6	10.2	469.2
5. Legs & feet	31.8	−13.7	−435.7	7.0	222.6
6. Upper seat structure	40.0	17.7	708.8	−1.3	−52.0
7. Lower seat structure	54.0	−8.5	−459.0	0.3	16.2
8. Seat Mechanisms	8.0	−3.6	−28.8	−0.8	−6.4
9. Parachutes	20.0	20.6	412.0	0.0	0.0
10. Initiation & Sequencing	7.0	−5.9	−41.3	2.9	20.3
11. Harness retractor	5.0	9.5	47.5	−1.7	−8.5
12. Personal Equipment	43.2	3.7	159.8	4.2	181.4
13. Harness, belts, cushions	14.0	−2.6	−36.4	1.4	19.6
14. Survival kit	38.0	−13.3	−505.4	0.7	26.6
15. Stabilization/Wedge	55.0	−22.4	−1232.0	8.0	440.0
Sub Totals	495.0	−0.3	−148.6	4.4	2183.4
16. Rocket	21.0	−0.3	−6.3	−6.3	−132.3
17. Propellant	7.0	−0.3	−2.1	−6.3	−44.1
Totals	523.0	−0.3	−157.0	3.8	2007.0

Inertia	$LB–IN^2$	$SLUG\ FT^2$	
I(XX)	32406	6.99	
I(YY)	143140	30.896	
I(ZZ)	142356	30.73	
I(XZ)	−4803.57	−1.04	
1787-137W			

TABLE A-3. ESCAPE SYSTEM CG – SHIELD/CANOPY CONCEPT
(95th Percentile Pilot)

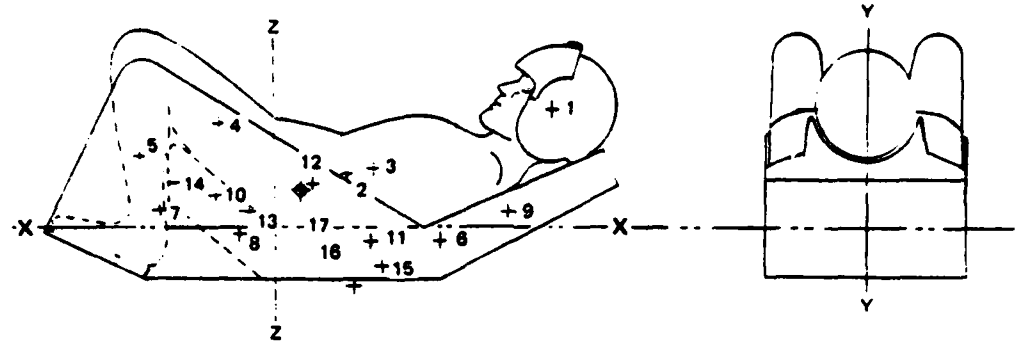


		WT	X	WX	Z	WZ
1.	Head	18.6	28.0	520.8	12.0	223.2
2.	Torso	87.4	7.7	672.9	5.4	471.9
3.	Arms	27.0	10.4	280.8	5.9	159.3
4.	Thighs	46.0	−4.6	−211.6	10.2	469.2
5.	Legs & feet	31.8	−13.7	−435.7	7.0	222.6
6.	Upper seat structure	31.0	15.4	477.4	−1.5	−46.5
7.	Lower seat structure	33.0	−11.9	−392.7	0.0	0.0
8.	Seat Mechanisms	8.0	−3.6	−28.8	−0.8	−6.4
9.	Parachutes	28.0	23.2	649.6	1.4	39.2
10.	Initiation & Sequencing	10.0	−5.9	−59.0	2.9	29.0
11.	Harness retractor	5.0	9.5	47.5	−1.7	−8.5
12.	Personal Equipment	43.2	3.7	159.8	4.2	181.4
13.	Harness, belts, cushions	14.0	−2.6	−36.4	1.4	19.6
14.	Survival kit	38.0	−10.0	−380.0	4.2	159.6
15.	Shield/Canopy/Interface	155.0	1.2	186.0	11.8	1829.0
	Sub Totals	576.0	2.6	1450.6	6.1	3742.6
16.	Rocket	21.0	−4.4	−92.4	−6.3	−132.3
17.	Propellant	12.0	−4.4	−52.8	−6.3	−75.6
	Totals	609.0	2.1	1306.4	5.8	3534.7

Inertia	$LB-IN^2$	$SLUG\ FT^2$	
I(XX)	70924.98	15.31	
I(YY)	273183.28	58.96	
I(ZZ)	272610.4	58.84	
I(XZ)	853.11	0.184	

1767-138W

TABLE A-4. ESCAPE SYSTEM CG – CURVED TRACK CONCEPT
(95^{th} Percentile Pilot)

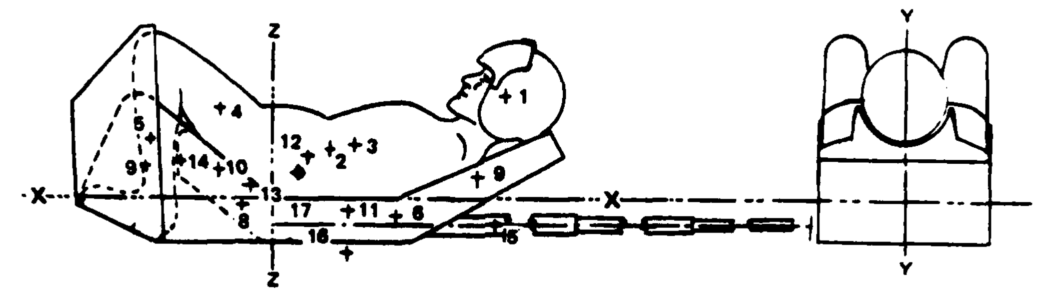


		WT	X	WX	Z	WZ
1.	Head	18.6	28.0	520.8	12.0	223.2
2.	Torso	87.4	7.7	672.9	5.4	471.9
3.	Arms	27.0	10.4	280.8	5.9	159.3
4.	Thighs	46.0	−4.6	−211.6	10.2	469.2
5.	Legs & feet	31.8	−13.7	−435.7	7.0	222.6
6.	Upper seat structure	40.0	16.5	660.0	−1.8	−72.0
7.	Lower seat structure	68.3	−11.2	−764.9	1.7	116.1
8.	Seat Mechanisms	8.0	−3.6	−28.8	−0.8	−6.4
9.	Parachutes	27.0	23.2	626.4	1.4	37.8
10.	Initiation & Sequencing	7.0	−5.9	−41.3	2.9	20.3
11.	Harness retractor	5.0	9.5	47.5	−1.7	−8.5
12.	Personal Equipment	43.2	3.7	159.8	4.2	181.4
13.	Harness, belts, cushions	14.0	−2.6	−36.4	1.4	19.6
14.	Survival kit	38.0	−10.0	−380.0	4.2	159.6
15.						
	Sub Totals	461.3	2.3	1069.5	4.3	1994.1
16.	Rocket	19.5	7.8	152.1	−5.9	−115.1
17.	Propellant	6.5	7.8	50.7	−5.9	−38.4
	Totals	487.3	2.6	1272.3	3.8	1840.6

Inertia	$LB-IN^2$	$SLUG\ FT^2$
I(XX)	31504.13	6.80
I(YY)	112263.08	24.23
I(ZZ)	113682.38	24.54
I(XZ)	−2435.21	−0.526

1787-139W

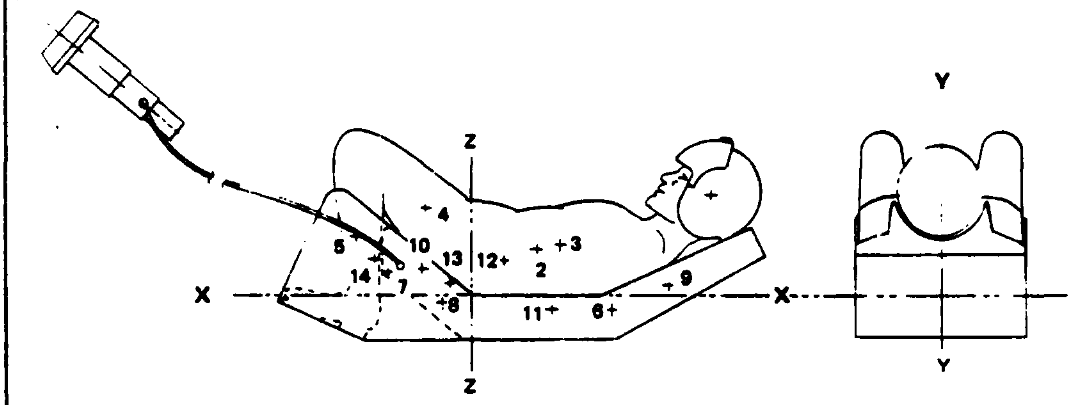
TABLE A-5. ESCAPE SYSTEM CG – "B" SEAT VARIANT CONCEPT
(95th Percentile Pilot)



	WT	X	WX	Z	WZ
1. Head	18.6	28.0	520.8	12.0	223.2
2. Torso	87.4	7.7	672.9	5.4	471.9
3. Arms	27.0	10.4	280.8	5.9	159.3
4. Thighs	46.0	−4.6	−211.6	10.2	469.2
5. Legs & feet	31.8	−13.7	−435.7	7.0	222.6
6. Upper seat structure	38.0	14.4	547.2	−2.3	−87.4
7. Lower seat structure	53.7	−15.0	−805.5	3.7	198.7
8. Seat Mechanisms	8.0	−3.6	−28.8	−0.8	−6.4
9. Parachutes	19.0	24.0	456.0	2.4	45.6
10. Initiation & Sequencing	10.0	−5.9	−59.0	2.9	29.0
11. Harness retractor	3.0	9.5	28.5	−1.7	−5.1
12. Personal Equipment	43.2	3.7	159.8	4.2	181.4
13. Harness, belts, cushions	14.0	−2.6	36.4	1.4	19.6
14. Survival kit	43.2	−10.0	−432.0	4.2	181.4
15. Stabilization Boom	32.0	26.0	832.0	−3.1	−99.2
Sub Totals	474.9	3.1	1488.7	4.2	2003.8
16. Rocket	20.5	8.8	180.4	−6.3	−129.2
17. Propellant	10.5	8.8	92.4	−6.3	−66.2
Totals	505.9	3.5	1761.5	3.6	1808.4

Inertia	LB–IN^2	SLUG FT^2
I(XX)	31273.94	6.75
I(YY)	128218.69	27.68
I(ZZ)	129650.22	27.98
I(XZ)	7086.57	−1.526
1787-140W		

TABLE A-6. ESCAPE SYSTEM CG – TRACTOR ROCKET CONCEPT
(95th Percentile Pilot)



	WT	X	WX	Z	WZ
1. Head	18.6	28.8	520.8	12.0	223.2
2. Torso	87.4	7.7	672.9	5.4	471.9
3. Arms	27.0	10.4	280.8	5.9	159.3
4. Thighs	46.0	−4.6	−211.6	10.2	469.2
5. Legs & feet	31.8	−13.7	−435.7	7.0	222.6
6. Upper seat structure	55.0	16.5	907.5	−1.7	−93.5
7. Lower seat structure	61.8	−10.0	−618.0	2.9	179.2
8. Seat Mechanisms	8.0	−3.6	−28.8	−0.8	−6.4
9. Parachutes	20.0	23.2	464.0	1.2	24.0
10. Initiation & Sequencing	10.0	−5.9	−59.0	3.2	32.0
11. Harness retractor	5.0	9.5	47.5	−1.6	−8.0
12. Personal Equipment	43.2	3.7	159.8	4.2	181.4
13. Harness, belts, cushions	14.0	−2.6	−36.4	1.4	19.6
14. Survival kit	38.0	−11.5	−437.0	4.4	167.2
15.					
Sub Totals	465.8	2.6	1226.8	4.4	2041.7
16. Rocket	22.0				
17. Propellant	6.0				
Totals	493.8				

Inertia	$LB-IN^2$	$SLUG\ FT^2$
I(XX)	29767.03	6.42
I(YY)	111191.89	24.00
I(ZZ)	116002.62	25.04
I(XZ)	−3254.88	−.702

1787-141W

APPENDIX B

ESCAPE CONCEPTS AERODYNAMIC DATA

TABLE B-1. DATA COMPARISON (WIND TUNNEL VS COMPUTER MODEL)

CONVENTIONAL SEAT

WIND TUNNEL DATA				NEWTONIAN DATA		
(°)	CA	CN	Cm	CA	CN	Cm
0.	1.247	−0.3930	0.1488	1.0653	0.0000	0.3842
5.	1.226	−0.2924	0.1609		−0−	
10.	1.198	−0.2147	0.1768	1.0332	0.0247	0.3761
15.	1.116	−0.1167	0.1868			
20.	1.017	0.0135	0.1887	0.9407	0.0959	0.3528
25.	0.891	0.1217	0.1871			
30.	0.835	0.2355	0.1865	0.6914	0.2049	0.2751
35.	0.698	0.3257	0.1781			
40.	0.615	0.4205	0.1748	0.4568	0.3386	0.1961
45.	0.513	0.5158	0.1723			
50.	0.434	0.5764	0.1685	0.3217	0.4809	0.1722
55.	0.361	0.6005	0.1613			
60.	0.277	0.6412	0.1691	0.1588	0.6146	0.1212
65.	0.208	0.6831	0.1606			
70.	0.156	0.7280	0.1623	0.0676	0.7236	0.1026
75.	0.080	0.7516	0.1687			
80.	−0.018	0.7845	0.1650	0.0148	0.7947	0.1120
85.	−0.123	0.8045	0.1613			
90.	−0.201	0.8135	0.1519	0.0000	0.8195	0.1154
95.	−0.278	0.8319	0.1359			
100.	−0.356	0.8270	0.1326	−0.0321	0.7948	0.1003
105.	−0.403	0.8048	0.1093			
110.	−0.508	0.8066	0.0908	−0.1246	0.7236	0.0569

1787-142(1)W

TABLE B-1. DATA COMPARISON (WIND TUNNEL VS COMPUTER MODEL) (CONTD)

CONVENTIONAL SEAT

WIND TUNNEL DATA				NEWTONIAN DATA		
(°)	CA	CN	Cm	CA	CN	Cm
115.	−0.587	0.7349	0.0443			
120.	^.841	0.8466	0.0114	−0.2863	0.6146	−0.0095
125.	−0.734	0.8351	0.0184			
130.	−0.823	0.8244	−0.0286	−0.4402	0.4809	−0.0911
135.	−0.913	0.8032	−0.0632			
140.	−0.991	0.7684	−0.0965	−0.6251	0.3386	−0.1778
145.	−1.058	0.7171	−0.1292			
150.	−1.112	0.6576	−0.1531	−0.7990	0.2049	−0.2593
155.	−1.128	0.5716	−0.1781			
160.	−1.189	0.4966	−0.2023	−0.9407	0.0969	−0.3258
165.	−1.136	0.3919	−0.2287			
170.	−1.125	0.2974	−0.2533	−1.0332	0.0247	−0.3692
175.	−1.045	0.2101	−0.2900			
180.	−1.059	0.1604	−0.3109	−1.0653	0.0000	−0.3842
185.	−1.025	0.1012	−0.3349			
190.	−0.965	0.0389	−0.3550	−1.0332	−0.0178	−0.3736
195.	−0.939	−0.0169	−0.3682			
200.	−0.880	−0.0678	−0.3767	−0.9407	−0.0690	−0.3425
205.	−0.828	−0.1020	−0.3799			
210.	−0.786	−0.1351	−0.3727	−0.7990	−0.1478	−0.2960
215.	−0.730	−0.1637	−0.3586			
220.	−0.673	−0.1949	−0.3387	−0.6251	−0.2438	−0.2367
225.	−0.591	−0.2345	−0.3093			
230.	−0.505	−0.2613	−0.2756	−0.4402	−0.3462	−0.1747
235.	−0.415	−0.2835	−0.2349			
240.	−0.447	−0.3089	−0.2142	−0.2863	−0.4425	−0.1164
245.	−0.349	−0.3463	−0.1746			

1767-142(2)W

TABLE B-1. DATA COMPARISON (WIND TUNNEL VS COMPUTER MODEL) (CONTD)

CONVENTIONAL SEAT

WIND TUNNEL DATA				NEWTONIAN DATA		
(°)	CA	CN	Cm	CA	CN	Cm
250.	−0.254	−0.3660	−0.1326	−0.1246	−0.5210	−0.0689
255.	−0.155	−0.3704	−0.0851			
260.	−0.064	−0.3929	−0.0584	−0.0321	−0.6835	−0.0987
265.	0.046	−0.4552	−0.0378			
270.	0.156	−0.5050	−0.0127	0.0000	−0.8195	−0.1154
275.	0.259	−0.5376	−0.0192			
280.	0.374	−0.5827	0.0503	0.0321	−0.7948	−0.1003
285.	0.494	−0.6437	0.0812			
290.	0.693	−0.6801	0.1112	0.1246	−0.7236	−0.0569
295.	0.740	−0.7048	0.1506			
300.	0.854	−0.7165	0.1880	0.2663	−0.6146	0.0095
305.	0.944	−0.7301	0.2057			
310.	1.005	−0.7172	0.2145	0.4402	−0.4809	0.0911
315.	1.056	−0.6931	0.2199			
320.	1.108	−0.6599	0.2172	0.6251	−0.3386	0.1778
325.	1.159	−0.6231	0.2065			
330.	1.195	−0.5795	0.2043	0.7990	−0.2049	0.2593
335.	1.210	−0.5388	0.1959			
340.	1.209	0.4965	0.1835	0.9407	−0.0959	0.3258
345.	1.197	−0.4548	0.2705			
350.	1.166	−0.4102	0.1632	1.0332	−0.0247	0.3692
355.	1.311	−0.3575	0.1361			

1787-142(3)W

APPENDIX C

ESCAPE CONCEPTS FUNCTIONAL ELEMENT MATRIX

TABLE C-1. FUNCTIONAL ELEMENTS MATRIX

(Note: STD=Standard; FR=Fixed Rocket; VS=Vertical Steering.)

ESCAPE SYS CONCEPT / FUNCTIONAL ELEMENTS	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED CONCEPT
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	
• SEAT STRUCTURE													
BUCKET	X	X	X	X	X	X	X	X	X	X	X	X	X
TRACKS/ROLLERS	X	X	X	X	X	X	X	X	X	X	X	X	X
MAIN STRUCTURE	X	X	X	X	X	X	X	X	X	X	X	X	X
HEAD SUPPORT	X	X	X	X	X	X	X	X	X	X	X	X	X
PARACHUTE SUPPORT	X	X	X	X	X	X	X	X	X	X	X	X	X
DROGUE SUPPORT	–	–	X	X	X	X	–	–	X	X	X	X	X
BACK SUPPORT	X	X	X	X	X	X	X	X	X	X	X	X	X
ROCKET SUPPORT	X	X	–	–	–	–	X	X	–	–	–	–	–
• SEAT MECHANISM													
ESCAPE INITIATION	X	X	X	X	X	X	X	X	X	X	X	X	X
SHOULDER HARNESS	X	X	X	X	X	X	X	X	X	X	X	X	X
DROGUE GUN	–	–	X	X	X	X	–	–	X	X	X	X	X
TIMING	X	X	X	X	X	X	X	X	X	X	X	X	X
BAROSTAT	X	X	X	X	X	X	X	X	X	X	X	X	X
SPEED SENSOR	X	X	X	X	X	X	X	X	X	X	X	X	X
ROCKET UPWARD CONTROL	–	X	–	X	–	X	–	X	–	X	–	X	X
DROGUE RELEASE	X	X	X	X	X	X	X	X	X	X	X	X	X
MAIN CANOPY RELEASE	X	X	X	X	X	X	X	X	X	X	X	X	X
SEAT ADJUSTMENT	X	X	X	X	X	X	X	X	X	X	X	X	X

1787-143W(1)

TABLE C-1. FUNCTIONAL ELEMENTS MATRIX (CONTD)
(Note: STD=Standard; FR=Fixed Rocket; VS=Vertical Steering.)

ESCAPE SYS CONCEPT / FUNCTIONAL ELEMENTS	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	CONCEPT
• STABILIZATION													
INFLATABLE	–	–	–	–	–	–	–	–	–	–	–	–	–
DROGUE	X	X	X	X	X	X	X	X	X	X	X	X	X
MAIN CANOPY	X	X	X	X	X	X	X	X	X	X	X	X	X
ROCKET	–	–	–	–	–	–	–	–	–	–	–	–	X
DROGUE STAGING	X	X	X	X	X	X	X	X	X	X	X	X	X
• SEAT SUBSYSTEMS													
DROGUES	X	X	X	X	X	X	X	X	X	X	X	X	X
MAIN CANOPY (28 FT)	X	X	X	X	X	X	X	X	X	X	X	X	X
HARNESS RELEASE	X	X	X	X	X	X	X	X	X	X	X	X	X
SURVIVAL EQUIPMENT	X	X	X	X	X	X	X	X	X	X	X	X	X
SERVICES													
•OXYGEN-REGULAR	X	X	X	X	X	X	X	X	X	X	X	X	X
OXYGEN-EMERGENCY	X	X	X	X	X	X	X	X	X	X	X	X	X
ANTI-"G" (VIA CONSOLE)	X	X	X	X	X	X	X	X	X	X	X	X	X
VENTILATION (VIA CONSOLE)	X	X	X	X	X	X	X	X	X	X	X	X	X
AUDIO (VIA CONSOLE)	X	X	X	X	X	X	X	X	X	X	X	X	X
• RESTRAINT													
– PASSIVE													
LEG GUARDS	–	–	X	X	X	X	–	–	X	X	X	X	X
HEAD REST	X	X	X	X	X	X	X	X	X	X	X	X	X
ARM REST	–	–	X	X	X	X	–	–	X	X	X	X	X
SEAT PAN	X	X	X	X	X	X	X	X	X	X	X	X	X
BACK PAD	X	X	X	X	X	X	X	X	X	X	X	X	X
LAP BELT	X	X	X	X	X	X	X	X	X	X	X	X	X
SHOULDER HARNESS	X	X	X	X	X	X	X	X	X	X	X	X	X

1787-143W(2)

TABLE C-1. FUNCTIONAL ELEMENTS MATRIX (CONTD)

(Note: STD=Standard; FR=Fixed Rocket; VS=Vertical Steering.)

ESCAPE SYS CONCEPT / FUNCTIONAL ELEMENTS	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	CONCEPT
– ACTIVE (SEAT MOTION)													
LEG RESTRAINT	–	–	–	–	–	–	–	–	–	–	–	–	X
ARM RESTRAINT	–	–	–	–	–	–	–	–	–	–	–	–	X
HEAD RESTRAINT	–	–	–	–	–	–	–	–	–	–	–	–	X
• MISC HARDWARE													
ROCKET LAUNCHER	X	X	–	–	–	–	X	X	–	–	–	–	–
ROCKET INITIATION	X	X	X	X	X	X	X	X	X	X	X	X	X
DROGUE GUN INITIATION	–	–	X	X	X	X	–	–	X	X	X	X	X
TIMING INITIATION	X	X	X	X	X	X	X	X	X	X	X	X	X
EMER OXY INITIATION	X	X	X	X	X	X	X	X	X	X	X	X	X
SEAT LOCK/UNLOCK	X	X	X	X	X	X	X	X	X	X	X	X	X
TRACK SUPPORT	X	X	X	X	X	X	X	X	X	X	X	X	X
ACFT INTERFACE SYS													
STRUCTURE SEPARATION	–	–	–	–	X	X	–	–	–	–	X	X	X
WINDSHIELD	–	–	–	–	X	X	–	–	–	–	X	X	X
INSTR PANEL	–	–	–	–	X	X	–	–	–	–	X	X	X
WIRING	–	–	–	–	X	X	–	–	–	–	X	X	X
CONTROLS	–	–	–	–	X	X	–	–	–	–	X	X	X
• SEPARATION GUIDE													
TRACKS/ROLLERS	X	X	X	X	X	X	X	X	X	X	X	X	X
TELESCOPING TRACKS	–	–	–	–	X	X	–	–	–	–	X	X	X
BOOSTER	X	X	X	X	X	X	X	X	X	X	X	X	X
CATAPULT	X	X	X	X	X	X	X	X	X	X	X	X	X
CARTRIDGE	X	X	X	X	X	X	X	X	X	X	X	X	X
BALLISTIC CANOPY	X	X	X	X	–	–	X	X	X	X	–	–	–

1787-143W(3)

TABLE C-1. FUNCTIONAL ELEMENTS MATRIX (CONTD)
(Note: STD=Standard; FR=Fixed Rocket; VS=Vertical Steering.)

ESCAPE SYS CONCEPT / FUNCTIONAL ELEMENTS	0 TO 450 KEAS						0 TO 600 KEAS						0 TO 687 KEAS
	TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		TRACTOR ROCKET		CURVED TRACK		SUPINE CONCEPT		PREFERRED
	STD	VS	FR	VS	FR	VS	STD	VS	FR	VS	FR	VS	CONCEPT
CANOPY CYLINDER	X	X	X	X	X	X	X	X	X	X	X	X	X
CNPY/WDSHLD/PNL	–	–	–	–	X	X	–	–	–	–	X	X	X
• SEAT SEPARATION													
MECHANICAL	–	–	X	X	X	X	–	–	X	X	X	X	X
• UPWARD CONTROL													
GIMBAL	–	–	–	X	–	X	–	–	–	X	–	X	X
MICRO PROCESSOR	–	X	–	X	–	X	–	X	–	X	–	X	X
POWER SUPPLY	–	X	–	X	–	X	–	X	–	X	–	X	X
B.D. ACCUMULATOR	–	X	–	X	–	X	–	X	–	X	–	X	X
SERVO ACTUATORS	–	X	–	X	–	X	–	X	–	X	–	X	X
RATE SENSOR	–	X	–	X	–	X	–	X	–	X	–	X	X
INTELLIGENCE SYS	–	X	–	X	–	X	–	X	–	X	–	X	X
MECHANISM	–	X	–	X	–	X	–	X	–	X	–	X	X
DUAL VECTOR NOZZLE	–	X	–	–	–	–	–	X	–	–	–	–	–
• VECTOR CONTROL													
INTELLIGENCE SYSTEM	–	–	–	–	–	–	–	–	–	–	–	–	X
• PROPULSION ROCKET													
2,000 LB (0.5 SEC)	X	–	–	–	–	–	X	–	–	–	–	–	–
2,000 LB (2.0 SEC)	–	X	–	–	–	–	–	X	–	–	–	–	–
3,500 LB (1.75 SEC)	–	–	–	–	–	–	–	–	–	–	–	–	–
5,000 LB (2.0 SEC)	–	–	–	X	–	X	–	–	–	X	–	X	X
5,000 LB (0.25 SEC)	–	–	X	–	X	–	–	–	X	–	X	–	–
• SPOILER SYS													
1787-143W(4)													

APPENDIX D

MODULAR LIFE CYCLE COST MODEL (MLCCM) DATA

```
*********************************************************************
******                     MLCCM OUTPUT                        ******
*********************************************************************
             THIS RUN WAS MADE ON 02/05/79 AT 14.46.32

 A/C DESIGNATION = FIGHTER BASE           LIFE CYCLE =  180.00 MONTHS
 OUTPUT YEAR     = 1979         S/S - PHASE SELECTED = 13 - 5

            ******  TOTAL COST = $   6.508 BILLION  ******

WANT PHASE AND SUBSYSTEM SUBTOTALS? --- 1=YES,0=NO

                 SUBTOTALS BY PHASE (IN MILLIONS)
                                                    UNIT       CUM FOR
                                                     100      3 TO  502
                                                   ------   -----------
  RDT&E( 2A/C)= $    391.8530   PRODUCTION  = $    5.3331 $  2415.5735
      AIRFRAME = $    306.303       AIRFRAME = $   4.169  $  1888.199
      ENGINE   = $      0.000       ENGINE   = $   0.000  $     0.000
      AVIONICS = $      0.000       AVIONICS = $   0.000  $     0.000
      G&A      = $     49.927       G&A      = $    .680  $   307.777
      PROFIT   = $     35.623       PROFIT   = $    .485  $   219.598

  INIT SUP     = $  . 237.4742  OPERATIONS & SUPPORT          = $  2569.0990
      CUST     = $    185.628       BASE MAINTENANCE          = $   366.588
         SPARES = $    32.711       BASE OPERATIONS           = $   297.604
         S E    = $    43.523       BASE TRAINING             = $   395.259
         CON TRN= $     0.000       DEPOT AIRFRAME            = $   146.440
         DATA   = $   109.395       DEPOT COMP REPAIR         = $   365.525
      G&A      = $     30.257       DEPOT ENGINE REPAIR       = $     0.000
      PROFIT   = $     21.589       REPLENISHMENT SPARES      = $   239.930
                                    OTHER                     = $     7.321
                                    NON-DESIGN RELATED        = $   750.432

                               PUL = $    895.254
```

1787-144W

Figure D-1. MLCCM Output for Fighter Baseline

```
******************************************************************************
******                        MLCCM OUTPUT                              ******
******************************************************************************
                 THIS RUN WAS MADE ON 02/06/79 AT 09,43,36

A/C DESIGNATION = FIGHTER MSLPC             LIFE CYCLE =  180.00 MONTHS
OUTPUT YEAR      = 1979           S/S - PHASE SELECTED = 13 - 5

             ******  TOTAL COST = $    6,469 BILLION  ******

WANT PHASE AND SUBSYSTEM SUBTOTALS? --- 1=YES,0=NO


                   SUBTOTALS BY PHASE (IN MILLIONS)
                                                       UNIT         CUM FOR
                                                        100        3 TO  502
                                                      ------      -----------
  RDT&E( 2A/C)= $     383.2427   PRODUCTION   = $     5.2776  $   2390.4859
     AIRFRAME = $     299.572       AIRFRAME  = $     4.125   $   1868.589
     ENGINE   = $       0.000       ENGINE    = $     0.000   $      0.000
     AVIONICS = $       0.000       AVIONICS  = $     0.000   $      0.000
     G&A      = $      48.830       G&A       = $      .672   $    304.580
     PROFIT   = $      34.840       PROFIT    = $      .480   $    217.317

  INIT SUP    = $     236.4279   OPERATIONS & SUPPORT         = $   2565.3434
     COST     = $     184.810       BASE MAINTENANCE          = $    366.548
       SPARES = $      32.080       BASE OPERATIONS           = $    294.105
       S E    = $      43.432       BASE TRAINING             = $    395.259
       CON TRN= $       0.000       DEPOT AIRFRAME            = $    150.099
       DATA   = $     109.298       DEPOT COMP REPAIR         = $    363.834
     G&A      = $      30.124       DEPOT ENGINE REPAIR       = $      0.000
     PROFIT   = $      21.493       REPLENISHMENT SPARES      = $    238.169
                                    OTHER                     = $      7.304
                                    NON-DESIGN RELATED        = $    749.726

                                 POL = $    895.254
```

1787-145W

Figure D-2. MLCCM Output for Fighter MSLPC

```
****************************************************************************
******                          MLCCM OUTPUT                          ******
****************************************************************************

                THIS RUN WAS MADE ON 02/06/79 AT 09.51.56

 A/C DESIGNATION = PENETR W/RAD BASE       LIFE CYCLE =  180.00 MONTHS
 OUTPUT YEAR      = 1979          S/S - PHASE SELECTED = 13 - 5

              ******  TOTAL COST = $   8.721 BILLION  ******

WANT PHASE AND SUBSYSTEM SUBTOTALS? --- 1=YES,0=NO

                  SUBTOTALS BY PHASE (IN MILLIONS)
                                                        UNIT        CUM FOR
                                                         100       3 TO  502
                                                       ------   -----------
 RDT&E( 2A/C)= $    750.5019   PRODUCTION   = $       7.2313 $   3274.1367
    AIRFRAME = $    586.650       AIRFRAME  = $       5.653  $   2559.319
    ENGINE   = $      0.000       ENGINE    = $       0.000  $      0.000
    AVIONICS = $      0.000       AVIONICS  = $       0.000  $      0.000
    G&A      = $     95.624       G&A       = $        .921  $    417.169
    PROFIT   = $     68.227       PROFIT    = $        .657  $    247.649

 INIT SUP    = $    305.3750   OPERATIONS & SUPPORT          = $   3475.4258
    COST     = $    238.705       BASE MAINTENANCE           = $    499.768
       SPARES = $    64.305       BASE OPERATIONS            = $    339.953
       S E    = $    55.622       BASE TRAINING              = $    501.192
       CON TRN= $     0.000       DEPOT AIRFRAME             = $    189.428
       DATA   = $   118.778       DEPOT COMP REPAIR          = $    498.803
    G&A      = $     38.909       DEPOT ENGINE REPAIR        = $      0.000
    PROFIT   = $     27.761       REPLENISHMENT SPARES       = $    446.460
                                  OTHER                      = $      9.986
                                  NON-DESIGN RELATED         = $    989.838

                               POL = $   917.977
```

1787-146W

Figure D-3. MLCCM Output for Penetrator Baseline

```
*******************************************************************
******                    MLCCM OUTPUT                      ******
*******************************************************************
           THIS RUN WAS MADE ON 02/06/79 AT 13,21,53

 A/C DESIGNATION = PENETR W/RAD MSLPC       LIFE CYCLE =  180,00 MONTHS
 OUTPUT YEAR      = 1979           S/S - PHASE SELECTED = 13 - 5

          ******  TOTAL COST = $   8,668 BILLION   ******


WANT PHASE AND SUBSYSTEM SUBTOTALS? --- 1=YES,0=NO


               SUBTOTALS BY PHASE (IN MILLIONS)
                                                     UNIT       CUM FOR
                                                      100      3 TO  502
                                                    ------   -----------
 RDT&E( 2A/C)= $   737.2662   PRODUCTION  = $       7.1608 $   3242.4688
    AIRFRAME = $   576.304       AIRFRAME = $       5.597  $   2534.565
    ENGINE   = $     0.000       ENGINE   = $       0.000  $      0.000
    AVIONICS = $     0.000       AVIONICS = $       0.000  $      0.000
    G&A      = $    93.938       G&A      = $        .912  $    413.134
    PROFIT   = $    67.024       PROFIT   = $        .651  $    294.770

 INIT SUP    = $   303.5485   OPERATIONS & SUPPORT          = $   3468.8545
   COST      = $   237.277       BASE MAINTENANCE           = $    498.591
     SPARES  = $    63.126       BASE OPERATIONS            = $    358.927
     S E     = $    55.481       BASE TRAINING              = $    501.192
     CON TRN = $     0.000       DEPOT AIRFRAME             = $    191.177
     DATA    = $   118.670       DEPOT COMP REPAIR          = $    497.374
   G&A       = $    38.676       DEPOT ENGINE REPAIR        = $      0.000
   PROFIT    = $    27.595       REPLENISHMENT SPARES       = $    443.764
                                 OTHER                      = $      9.960
                                 NON-DESIGN RELATED         = $    988.289

                              PUL = $   917,977
```

1787-147W

Figure D-4. MLCCM Output for Penetrator MSLPC With Radar

```
*********************************************************************
******                      MLCCM OUTPUT                      ******
*********************************************************************

              THIS RUN WAS MADE ON 02/06/79 AT 09.57.41

 A/C DESIGNATION = PENETR W/O RAD MSLPC    LIFE CYCLE =  180.00 MONTHS
 OUTPUT YEAR      = 1979          S/S - PHASE SELECTED = 13 - 5

             ******  TOTAL COST = $   8.613 BILLION  ******

WANT PHASE AND SUBSYSTEM SUBTOTALS? --- 1=YES,0=NO

                  SUBTOTALS BY PHASE (IN MILLIONS)
                                                     UNIT        CUM FOR
                                                      100       3 TO  502
                                                    ------     -----------
  RDT&E( 2A/C)= $    722.6691   PRODUCTION   = $    7.0864 $   3209.1002
      AIRFRAME = $    564.894       AIRFRAME = $    5.539  $   2508.481
      ENGINE   = $      0.000       ENGINE   = $    0.000  $      0.000
      AVIONICS = $      0.000       AVIONICS = $    0.000  $      0.000
      G&A      = $     92.078       G&A      = $     .903  $    408.882
      PROFIT   = $     65.697       PROFIT   = $     .644  $    241.736

  INIT SUP     = $    301.5486  OPERATIONS & SUPPORT          = $  3463.9400
     COST      = $    235.714       BASE MAINTENANCE          = $   497.665
        SPARES = $     61.814       BASE OPERATIONS           = $   337.332
        S E    = $     55.339       BASE TRAINING             = $   501.192
        CON TRN= $      0.000       DEPOT AIRFRAME            = $   192.954
        DATA   = $    118.560       DEPOT COMP REPAIR         = $   496.221
     G&A       = $     38.421       DEPOT ENGINE REPAIR       = $     0.000
     PROFIT    = $     27.414       REPLENISHMENT SPARES      = $   441.607
                                    OTHER                     = $     9.939
                                    NON-DESIGN RELATED        = $   987.050

                                POL = $   917.977
```

1787-148W

Figure D-5. MLCCM Output for Penetrator MSLPC Without Radar

```
********************  CREW SYSTEM SUBSYSTEM  ********************
                * INPUT DESIGN PARAMETERS *
NOSEATS =        1.00    FSLGVOL  =    1189.00    TYPSEAT  =        2.00
LHNCSS  =         .95    NOACMFG  =     502.00    NOENG    =        2.00
FSLGDEN =       15.34    NOCREW   =       1.00    MAXMACH  =        1.60
TPP     =      372.00    NUAC     =     397.00    FHPAC    =       25.00
NUACPSQ =       24.00    NOBSE(1) =       0.00    NOBSE(2) =        2.00
NOBSE(3)=        4.00    UTLRATE  =     300.00    PROTO    =        2.00
TOTHRST =    24791.00

                  * COST (IN MILLIONS) *
                        PROD
                        ------
                           UNIT          CUM FOR
                            100         3 TO  502
                          ------      ----------
S/S PROD COST  = $          .060   $     28.818
FINAL ASSY     = $          .007   $      3.269
               ------------------   ----------
               $           .0671   $    32.0875

       I S                                         O & S
      -----                                       -------
SPARES           = $      .479   BASE MAINTENANCE   = $        2.352
SUPPORT EQUIP    = $      .239   BASE OPERATIONS    = $       17.504
CONTRACTED TRNG  = $     0.000   BASE TRAINING      = $       23.367
DATA             = $     1.402   DEPOT AIRFRAME     = $        9.820
                   -----------   DEPOT COMP REPAIR  = $       12.049
                   $    2.1205   REPLEN SPARES      = $       12.888
                                 OTHER              = $         .144
                                 NON-DESIGN REL     = $       32.526
                                                      ------------
                                                      $     110.7453
```

1787-149W

Figure D-6. Crew System LCC for Fighter Baseline

```
********************** CREW SYSTEM SUBSYSTEM ********************

                  * INPUT DESIGN PARAMETERS *

NOSEATS =        1.00   FSLGVOL  =    1155.00   TYPSEAT  =      5.00
LRNCSS  =         .95   NOACMFG  =     502.00   NUENG    =      2.00
FSLGDEN =       12.49   NOCREW   =       1.00   MAXMACH  =      1.60
TFP     =      372.00   NOAC     =     397.00   FHPAC    =     25.00
NOACPSQ =       24.00   NOBSE(1) =       0.00   NOBSE(2) =      2.00
NOBSE(3)=        4.00   UTLRATE  =     300.00   PROTO    =      2.00
TOTHRST =    24014.00

                    * COST (IN MILLIONS) *

                         PROD
                        ------
                           UNIT           CUM FOR
                            100           5 TO  502
                          ------        ----------
       S/S PROD COST = $       .059   $      28.217
       FINAL ASSY    = $       .007   $       3.221
                     -----------      ----------
                     $        .0658 $       31.4384

             I S                                      O & S
            -----                                    -------
SPARES            = $         .464  BASE MAINTENANCE   = $      2.501
SUPPORT EQUIP     = $         .231  BASE OPERATIONS    = $     17.387
CONTRACTED TRNG   = $        0.000  BASE TRAINING      = $     23.367
DATA              = $        1.402  DEPOT AIRFRAME     = $     10.072
                    -----------     DEPOT COMP REPAIR  = $     12.049
                    $       2.0966  REPLEN SPARES      = $     12.774
                                    OTHER              = $       .145
                                    NON-DESIGN REL     = $     32.613
                                                         ----------
                                                         $   110.9082
```

1787-150W

Figure D-7. Crew System LCC for Fighter MSLPC

```
********************  CREW SYSTEM SUBSYSTEM  ********************

               *  INPUT DESIGN PARAMETERS  *

NOSEATS  =       1.00   FSLGVOL  =   2208.00   TYPSEAT  =    2.00
LRNCSS   =        .95   NOACMFG  =    502.00   NOENG    =    2.00
FSLGDEN  =       8.87   NOCREW   =      1.00   MAXMACH  =    2.00
TFF      =     372.00   NOAC     =    197.00   FHPAC    =   30.80
NOACPSQ  =      24.00   NOBSE(1) =      0.00   NOBSE(2) =    2.00
NOBSE(3) =       4.00   UTLRATE  =    370.00   PROTO    =    2.00
TOTMHST  =   32783.00

               * COST (IN MILLIONS) *

                          PROD
                          ------
                             UNIT        CUM FOR
                              100       3 TO  502
                            ------     ----------
        S/S PROD COST  = $    .095   $    45.182
        FINAL ASSY     = $    .009   $     4.320
                         ----------    ----------
                         $   .1036   $   49.5019

           I S                                        O & S
          -----                                      -------
SPARES           = $      .980   BASE MAINTENANCE   = $      .505
SUPPORT EQUIP    = $      .290   BASE OPERATIONS    = $    20.098
CONTRACTED TRNG  = $     0.000   BASE TRAINING      = $    29.630
DATA             = $     2.552   DEPOT AIRFRAME     = $    12.711
                   -----------   DEPOT COMP REPAIR  = $    14.844
                   $    3.8227   REPLEN SPARES      = $    14.115
                                 OTHER              = $      .153
                                 NON-DESIGN REL     = $    34.879
                                                      -----------
                                                      $  126.9355
```

1787-151W

Figure D-8. Crew System LCC for Penetrator Baseline

CREW SYSTEM SUBSYSTEM

* INPUT DESIGN PARAMETERS *

NOSEATS =	1.00	FSLGVOL =	2182.00	TYPSEAT =	2.00
LRNCSS =	.95	NOACMFG =	502.00	NOENG =	2.00
FSLGDEN =	8.91	NOCREW =	1.00	MAXMACH =	2.00
TFF =	372.00	NOAC =	397.00	FHPAC =	30.80
NOACPSQ =	24.00	NOMSE(1) =	0.00	NOMSE(2) =	2.00
NOMSE(3) =	4.00	UTLRATE =	370.00	PROTO =	2.00
TOTMRST =	32414.00				

* COST (IN MILLIONS) *

PROD

	UNIT 100	CUM FOR 1 TO 502
S/S PROD COST =	$ .094	$ 44.795
FINAL ASSY =	$ .009	$ 4.292
	$ .1027	$ 49.0877

I S

SPARES =	$ .967
SUPPORT EQUIP =	$ .286
CONTRACTED TRNG =	$ 0.000
DATA =	$ 2.552
	$ 3.8057

O & S

BASE MAINTENANCE =	$ .517
BASE OPERATIONS =	$ 20.014
BASE TRAINING =	$ 29.630
DEPOT AIRFRAME =	$ 12.828
DEPOT COMP REPAIR =	$ 14.844
REPLEN SPARES =	$ 14.064
OTHER =	$ .154
NON-DESIGN REL =	$ 34.883
	$ 126.9336

1787-152W

Figure D-9. Crew System LCC for Penetrator MSLPC With Radar

```
********************  CREW SYSTEM SUBSYSTEM  ********************

                    *  INPUT DESIGN PARAMETERS  *

NOSEATS  =        1.00   FSLGVOL  =    2156.00   TYPSEAT  =      2.00
LRNCSS   =         .95   NOACMFG  =     502.00   NOENG    =      2.00
FSLGDEN  =        8.95   NOCREW   =       1.00   MAXMACH  =      2.00
TFF      =      372.00   NOAC     =     397.00   FHPAC    =     30.80
NOACPSQ  =       24.00   NOBSE(1)=        0.00   NOBSE(2)=       2.00
NOBSE(3)=         4.00   UTLRATE  =     370.00   PHOTO    =      2.00
TOTHRST  =    32107.00

                       * COST (IN MILLIONS) *

                           PROD
                           ------
                              UNIT         CUM FOR
                               100        3 TO  502
                            ------      ----------
        S/S PROD COST  = $       .093   $    44.407
        FINAL ASSY     = $       .009   $     4.265
                         ----------     ----------
                         $      .1018   $   44.6720

           I S                                          O & S
          -----                                        -------
SPARES           = $      .954  BASE MAINTENANCE   = $       .529
SUPPORT EQUIP    = $      .283  BASE OPERATIONS    = $     19.943
CONTRACTED TRNG  = $     0.000  BASE TRAINING      = $     29.630
DATA             = $     2.552  DEPOT AIRFRAME     = $     12.946
                   ----------   DEPOT COMP REPAIR  = $     14.844
                   $    3.7894  REPLEN SPARES      = $     14.013
                                OTHER              = $       .154
                                NON-DESIGN REL     = $     34.890
                                                     ----------
                                                     $   126.9489
```

1787-153W

Figure D-10. Crew System LCC for Penetrator MSLPC Without Radar

APPENDIX E

FIGHTER APPLICATION DATA

CDAF PROGRAM

M1.6 FIGHTER CONFIGURATION

MISSION PROFILE

```
*******************************************
 COMPUTERIZED INITIAL SIZING ESTIMATE

***LAND-BASED DESIGN***  FIGHTER-ATTACK  F.WING-CANARD  AVIONICS=1100
RETAINED STORE-WT=    0  0.80 DRAG=0.0   .95 DRAG=0.0   1.1 DRAG=0.0
         1.4 DRAG= 0.0   1.80 DRAG=0.0   2.1 DRAG=0.0   2.5 DRAG=0.0
EXTERNAL STORE-WT=    0  0.80 DRAG=0.0   .95 DRAG=0.0   1.1 DRAG=0.0
         1.4 DRAG= 0.0   1.80 DRAG=0.0   2.1 DRAG=0.0   2.5 DRAG=0.0
EXT.TANK-CAPACITY=    0  0.80 DRAG=0.0   .95 DRAG=0.0   1.1 DRAG=0.0
         1.4 DRAG= 0.0   1.80 DRAG=0.0   2.1 DRAG=0.0   2.5 DRAG=0.0
INTERNAL STORE WT= 1000  CREW + PASS= 1  MAX.MACH=1.90  ULT.L.F.= 9.8
NO.OF INTERNAL RACKS= 4  EXT. RACKS = 0  PYLON NO. = 0  FIXED WT=1891
WING MTL. PCT.SAVING=33  V.TAIL PCT.=31  H.TAIL PCT=27  BODY PCT. =29
GEAR MTL. PCT.SAVING=25  A.IND. PCT.=27  GROWTH PCT= 0  SFC FACTOR= 5
SEA-LEVEL MAX.MACH=1.20  ENG. T/W= 0.0   *ENGINE EQUIPPED WITH AN A/B
HOURLY RATES-ENG.= 0.0   MANUFAC.= 0.0   MFG.SUP= 0.0   Q.CNTL.= 0.0
FLIGHT TEST RATE = 0.0   MANGMENT= 0.0   TOOLING= 0.0   $ REF.YR=   0
PRODUCTION QUANT.=    0  IOC YEAR=    0  G.AND A=.0     PROFIT =.0
THE MISSION PROFILE IS SHOWN BELOW
    WARMUP 15.00 MINUTES AT   7 PCT POWER
    TAKEOFF AND ACCELERATE TO CLIMB SPEED WITH 100 PCT MAX.AB
    DUMMY SEGMENT (    0FT/MACH 0.40)
    MINIMUM FUEL ACCEL =100 PCT POWER  TO     0FT/MACH 0.90 IN ***SEC
    CLIMB TO CRUISE ALTITUDE AT MACH 0.90 AND 100 PCT POWER
    CRUISE  100NM. AT BEST ALTITUDE AND MACH NUMBER
    MINIMUM FUEL ACCEL =100 PCT MAX.AB TO 41500FT/MACH 1.60 IN ***SEC
    CLIMB TO CRUISE ALTITUDE AT MACH 1.60 AND 100 PCT MAX.AB
    CRUISE  250NM. AT BEST ALTITUDE AND MACH 1.60
    COMPUTE MAX.TURN CAPABILITY- 30000FT/MACH 1.20 AND 100 PCT MAX.AB
    COMBAT-1.0 TURNS AT 5.74G ,30000FT/MACH 1.20
    COMPUTE MAX.TURN CAPABILITY- 30000FT/MACH 0.90 AND 100 PCT MAX.AB
    COMBAT-2.0 TURNS AT 4.93G ,30000FT/MACH 0.90
    COMPUTE MAX.TURN CAPABILITY- 30000FT/MACH 0.90 AND 100 PCT MAX.AB
    COMPUTE MAX.TURN CAPABILITY- 50000FT/MACH 1.60 AND 100 PCT MAX.AB
    DUMMY SEGMENT (30000FT/MACH 0.90)
    MINIMUM TIME ACCEL =100 PCT MAX.AB TO 30000FT/MACH 1.60 IN ***SEC
    DROP EXPENDABLE STORES
    CRUISE  250NM. AT BEST ALTITUDE AND MACH 1.60
    DUMMY SEGMENT (    0FT/MACH 0.90)
    CRUISE  100NM. AT BEST ALTITUDE AND MACH NUMBER
    LOITER   20MIN AT     0FT AND BEST MACH NUMBER
    FUEL ALLOWANCE EQUALS  5.0 PERCENT OF TOTAL FUEL
```

1787-154W

CDAF PROGRAM

M1.6 FIGHTER CONFIG. NO. 007

DATA

```
                        ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  365  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=57.0  TAPER=0.150
V.T.-AREA=   70  AR= 1.03  T/C(AVG)=.036  .25 SWEEP=52.8  TAPER=0.168
H.T.-AREA=   56  AR= 2.68  T/C(AVG)=.036  .25 SWEEP=46.7  TAPER=0.160
BODY-AREA=  826  WD= 5.19  LEN.,FT.=  56  VOL:TOT.= 1184  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 355  DUCT LEN=17.56  ENGS.=    2
TOTAL WETTED AREA  = 1629  CL(MAX.)=1.03  LANDING STALL SPEED,KN= 118
HORIZONTAL TAIL ARM, FEET= 16.8   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =10.04   TOTAL THRUST-SLS,MAXIMUM A/B= 24625
TAKEOFF WING LOADING, W/S= 65.7   TAKEOFF THRUST-TO-WEIGHT,T/W= 1.028
TAKEOFF DIST.(GROUND RUN)=  925   LANDING DISTANCE(GROUND RUN)=  1065

                        WEIGHT BREAKDOWN
WT. EMPTY   =  15492  WING   =  1811  FUEL SYST.=  902  AIR COND=   432
  CREW WT. =     240  V.TAIL=   295  MISC.PROP.=  163  HANDLING=     6
  RACKS,PYL=     300  H.TAIL=   305  SURF.CNTLS=  523  FIXED WT=  1891
  MISC.U.L.=     293  BODY   =  2594  HYDRAULICS=  326  GROWTH  =     0
  STORE WT.=    1000  GEAR   =   822  ELECTRICAL=  570  FLT.DES.= 22631
  TOT.FUEL =    6618  E.SECT=   483  AVIONICS  = 1736  STR.DEN.=  7.71
TAKEOFF WT.=   23944  ENGINE=  2370  FURN+EQUIP=  257  AIRFRAME=  9133

                        FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D    T.AVL    DRAG   SFC      TIME      FUEL
   0.0       0  0.0     0.0    15985    1119  1.643    15.0MIN      460
   0.0       0  0.40   11.56   23684    2024  1.904*    0.0MIN      181
   0.0       0  0.40    0.0        0       0  0.0       0.0MIN        0
   3.5       0  0.90    4.19   17488    5539  1.309    29.1SEC      170
  18.9   40500  0.90   12.54    4890    1815  1.154     2.2MIN      436
  62.4   41500  0.90   12.56    4662    1787  1.215     7.2MIN      265
  15.2   41500  1.60    3.95   12905    5626  1.979*   77.3SEC      403
  14.5   58500  1.60    6.70    5650    3256  1.996*    1.0MIN      261
 235.5   59500  1.60    6.68    3198    3093  1.353    15.4MIN     1102
P(S) AVAIL=    0  P(S) REQ=     0 AT  5.74G, 30000 FT,MACH 1.20(CL=0.51)
   8.1   30000  1.20    7.80   15236   15187  1.932*    0.7MIN      337
P(S) AVAIL=    0  P(S) REQ=     0 AT  4.93G, 30000 FT,MACH 0.90(CL=0.78)
  10.7   30000  0.90    8.41   12119   12095  1.864*    1.2MIN      455
P(S) AVAIL=    0  P(S) REQ=     0 AT  4.50G, 30000 FT,MACH 0.90(CL=0.78)
P(S) AVAIL=    0  P(S) REQ=     0 AT  2.54G, 50000 FT,MACH 1.60(CL=0.36)
   0.0   30000  0.90    0.0        0       0  0.0       0.0MIN        0
  10.1   30000  1.60    2.46   19966    9193  2.045*   49.8SEC        0
DROP STORES AT 50000. FEET
 250.0   62500  1.60    6.68    2761    2676  1.357    16.3MIN     1016
   0.0       0  0.90    0.0        0       0  0.0       0.0MIN        0
 100.0   52000  0.90   12.29    2826    1428  1.146    11.6MIN      320
  62.8       0  0.28   11.31   16372    1474  1.767    20.0MIN      881
   0.0       0  0.0     0.0        0       0  0.0       0.0MIN      331
COMBAT WEIGHT= 22630.LBS.
RUN ON 10/30/78 WITH 1977B VERSION OF CISE
CDAF MACH 1.6 FIGHTER FWC  (2) CDAFYJ18 ENGINES  FTRLAST POL
AR
```

1787-155W

BASELINE M1.6 FIGHTER

ASL-495F-007A

BASELINE DATA

```
                    ****RESULTS****
 WING SIZING CRITERION: INPUTTED W/S
 THRUST SIZING CRITERION: INPUTTED T/W
 WING-AREA=  368   AR= 3.00   T/C-ROOT=.045  L.E SWEEP=57.0  TAPER=0.150
U.T.-AREA=    71   AR= 1.03   T/C(AVG)=.036  .25 SWEEP=52.8  TAPER=0.168
H.T.-AREA=    57   AR= 2.68   T/C(AVG)=.036  .25 SWEEP=46.7  TAPER=0.160
BODY-AREA=  828  WD= 5.20   LEN.,FT.=  56   VOL:TOT.= 1189  PRESS=   80
ENG. NACELLES AREA =     0   CAP.AREA= 358   DUCT LEN=17.58  ENGS.=    2
TOTAL WETTED AREA   = 1640   CL(MAX.)=1.03   LANDING STALL SPEED,KN= 117
HORIZONTAL TAIL ARM, FEET= 16.8    DRAG RISE MACH NUMBER          = 0.900
OVERALL FINENESS RATIO    =10.02    TOTAL THRUST-SLS,MAXIMUM A/B= 24791
TAKEOFF WING LOADING, W/S= 65.6    TAKEOFF THRUST-TO-WEIGHT,T/W= 1.027
TAKEOFF DIST.(GROUND RUN)=  925    LANDING DISTANCE(GROUND RUN)=  1065

                     WEIGHT BREAKDOWN
WT. EMPTY  =   15589  WING   =  1831  FUEL SYST.=  906  AIR COND=   432
  CREW WT. =     279  U.TAIL=   298  MISC.PROP.=  163  HANDLING=     6
  RACKS,PYL=     300  H.TAIL=   309  SURF.CNTLS=  526  FIXED WT=  1891
  MISC.U.L.=     294  BODY  =  2606  HYDRAULICS=  327  GROWTH   =     0
  STORE WT.=    1000  GEAR  =   827  ELECTRICAL=  571  FLT.DES.= 22805
  TOT.FUEL =    6665  E.SECT=   486  AVIONICS  = 1736  STR.DEN.=  7.74
TAKEOFF WT.=  24128  ENGINE=  2389  FURN+EQUIP=  278  AIRFRAME=  9208

                     FUEL BREAKDOWN
  DIST.    ALT.   MACH    L/D    T.AVL    DRAG   SFC      TIME       FUEL
   0.0       0   0.0    0.0    16092    1126  1.643    15.0MIN      463
   0.0       0   0.40  11.57   23843    2037  1.904*    0.0MIN      183
   0.0       0   0.40   0.0        0       0  0.0       0.0MIN        0
   3.5       0   0.90   4.20   17605    5576  1.309    29.2SEC      171
  19.0  40500   0.90  12.55    4923    1827  1.154     2.2MIN      439
  62.3  41500   0.90  12.58    4693    1798  1.215     7.2MIN      267
  15.2  41500   1.60   3.95   12991    5669  1.979*   77.4SEC      406
  14.5  53500   1.60   6.70    5688    3279  1.996*    1.0MIN      263
 235.5  59500   1.60   6.69    3219    3115  1.353    15.4MIN     1110
P(S) AVAIL=    0   P(S) REQ=    0 AT  5.74G, 30000 FT.MACH 1.20(CL=0.51)
   3.1  30000   1.20   7.81   15333   15289  1.932*    0.7MIN      340
P(S) AVAIL=    0   P(S) REQ=    0 AT  4.93G, 30000 FT,MACH 0.90(CL=0.78)
  10.7  30000   0.90   8.42   12200   12176  1.864*    1.2MIN      458
P(S) AVAIL=    0   P(S) REQ=    0 AT  4.50G, 30000 FT,MACH 0.90(CL=0.78)
P(S) AVAIL=    0   P(S) REQ=    0 AT  2.54G, 50000 FT,MACH 1.60(CL=0.36)
   0.0  30000   0.90   0.0        0       0  0.0       0.0MIN        0
  10.2  30000   1.60   2.46   20100    9263  2.045*   49.8SEC        0
DROP STORES AT 50000. FEET
 250.0  62500   1.60   6.68    2779    2696  1.357    16.3MIN     1024
   0.0       0   0.90   0.0        0       0  0.0       0.0MIN        0
 100.0  52000   0.90  12.30    2845    1438  1.146    11.6MIN      322
  62.8       0   0.28  11.32   16481    1485  1.766    20.0MIN      888
   0.0       0   0.0    0.0        0       0  0.0       0.0MIN      333
COMBAT WEIGHT= 22805.LBS.
RUN ON 02/02/79 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC  (2) CDAFYJ18 ENGINES  FTRLAST PO
 LAR
```

1787-156W

MSLPC APPLICATION

FIGHTER CONFIG NO. 007LPC

AERO FACTORS DATA

```
                         ****RESULTS****
WING SIZING CRITERION  INPUTTED W/S
THRUST SIZING CRITERION  INPUTTED T/W
WING-AREA=  365  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=57.0  TAPER=0.150
V T -AREA=   68  AR= 1.03  T/C(AVG)=.036  .25 SWEEP=52.8  TAPER=0.168
H.T -AREA=   56  AR= 2.68  T/C(AVG)=.036  .25 SWEEP=46.7  TAPER=0.160
BODY-AREA=  811  WD= 5.12  LEN.,FT.=  56  VOL TOT.= 1155  PRESS=   80
ENG  NACELLES AREA =    0  CAP.AREA= 346  DUCT LEN=17.41  ENGS.=    2
TOTAL WETTED AREA  = 1613  CL(MAX.)=1.03  LANDING STALL SPEED,KN= 117
HORIZONTAL TAIL ARM, FEET= 16.7   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   = 9.99   TOTAL THRUST-SLS,MAXIMUM A/B= 24014
TAKEOFF WING LOADING, W/S= 64.8   TAKEOFF THRUST-TO-WEIGHT,T/W= 1.016
TAKEOFF DIST.(GROUND RUN)=  923   LANDING DISTANCE(GROUND RUN)=  1064

                      WEIGHT BREAKDOWN
WT. EMPTY  =  15330  WING  =  1802  FUEL SYST.=  888  AIR COND=   432
  CREW WT. =    279  V.TAIL=   286  MISC.PROP.=  161  HANDLING=     6
  RACKS/PYL=    300  H.TAIL=   304  SURF.CNTLS=  519  FIXED WT=  1891
  MISC.U.L.=    290  BODY  =  2546  HYDRAULICS=  324  GROWTH  =     0
  STORE WT.=   1000  GEAR  =   814  ELECTRICAL=  567  FLT.DES.= 22349
  TOT.FUEL =   6430  E.SECT=   470  AVIONICS  = 1736  STR.DEN.=  7.84
TAKEOFF WT.=  23630  ENGINE=  2300  FURN+EQUIP=  278  AIRFRAME=  9051

                      FUEL BREAKDOWN
 DIST.   ALT.   MACH    L/D    T AVL    DRAG   SFC      TIME      FUEL
   0.0      0   0.0     0.0    15588    1091  1.643    15.0MIN     448
   0.0      0   0.40   11.60   23096    1990  1.904*    0.0MIN     179
   0.0      0   0.40    0.0        0       0  0.0       0.0MIN       0
   3.6      0   0.90    4.18   17054    5483  1.309    29.6SEC     168
  19.2  40500   0.90   12.60    4768    1783  1.154     2.3MIN     431
  62.0  41500   0.90   12.63    4546    1754  1.212     7.2MIN     258
  15.2  41500   1.60    4.07   12584    5392  1.979*   77.5SEC     393
  15.2  59000   1.60    6.94    5377    3103  1.997*    1.0MIN     263
 234.8  60000   1.60    6.93    3043    2951  1.354    15.4MIN    1049
P(S) AVAIL=    0  P(S) REQ=    0 AT  5.78G, 30000 FT,MACH 1.20(CL=0.51)
   8.0  30000  1.20    7.97   14857   14810  1.932*    0.7MIN     326
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.92G, 30000 FT,MACH 0.90(CL=0.77)
  10.7  30000  0.90    8.52   11818   11797  1.864*    1.2MIN     444
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.50G, 30000 FT,MACH 0.90(CL=0.77)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.56G, 50000 FT,MACH 1.60(CL=0.36)
   0.0  30000  0.90    0.0        0       0  0.0       0.0MIN       0
  10.2  30000  1.60    2.54   19471    8804  2.045*   49.9SEC       0
DROP STORES AT 50000. FEET
 250.0  63000  1.60    6.93    2627    2556  1.358    16.3MIN     971
   0.0      0  0.90    0.0        0       0  0.0       0.0MIN       0
 100.0  51500  0.90   12.43    2822    1400  1.149    11.6MIN     314
  63.9      0  0.29   11.42   15978    1447  1.767    20.0MIN     865
   0.0      0  0.0     0.0        0       0  0.0       0.0MIN     322
COMBAT WEIGHT= 22349.LBS.
RUN ON 01/24/79 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC  (2) CDAFYJ18 ENGINES  FTRLAST PO
LAR
```

1787-157W

DEFLECTION WEDGE APPLICATION

TO

MSLPC/FIGHTER CONFIG. NO. 007 LPC

ESCAPE FACTORS DATA

```
                            ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  366  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=57.0  TAPER=0.150
V.T.-AREA=   68  AR= 1.03  T/C(AVG)=.036  .25 SWEEP=52.8  TAPER=0.168
H.T.-AREA=   56  AR= 2.68  T/C(AVG)=.036  .25 SWEEP=46.7  TAPER=0.160
BODY-AREA=  812  WD= 5.12  LEN.,FT.=  56  VOL:TOT.= 1157  PRESS=    80
ENG. NACELLES AREA =    0  CAP.AREA= 347  DUCT LEN=17.42  ENGS.=     2
TOTAL WETTED AREA  = 1616  CL(MAX.)=1.03  LANDING STALL SPEED,KN=  117
HORIZONTAL TAIL ARM, FEET= 16.7  DRAG RISE MACH NUMBER      = 0.900
OVERALL FINENESS RATIO   = 9.99  TOTAL THRUST-SLS,MAXIMUM A/B= 24075
TAKEOFF WING LOADING, W/S= 64.8  TAKEOFF THRUST-TO-WEIGHT,T/W= 1.016
TAKEOFF DIST.(GROUND RUN)=  923  LANDING DISTANCE(GROUND RUN)=  1064

                            WEIGHT BREAKDOWN
WT. EMPTY   =   15379  WING   =  1808  FUEL SYST.=  889  AIR COND=   432
  CREW WT. =      274  V.TAIL=    287  MISC.PROP.=  162  HANDLING=     6
  RACKS,PYL=      300  H.TAIL=    305  SURF.CNTLS=  520  FIXED WT=  1891
  MISC.U.L.=      290  BODY   =  2550  HYDRAULICS=  324  GROWTH   =    0
  STORE WT.=     1000  GEAR   =   816  ELECTRICAL=  568  FLT.DES.= 22407
  TOT.FUEL =     6446  E.SECT=    471  AVIONICS  = 1736  STR.DEN.=  7.86
TAKEOFF WT.=    23690  ENGINE=   2307  FURN+EQUIP=  302  AIRFRAME=  9093

                            FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D     T.AVL     DRAG   SFC       TIME       FUEL
   0.0       0   0.0     0.0     15628     1094  1.643     15.0MIN      449
   0.0       0   0.40   11.61    23155     1994  1.904*     0.0MIN      180
   0.0       0   0.40    0.0         0        0  0.0        0.0MIN        0
   3.6       0   0.90    4.18    17097     5493  1.309     29.6SEC      169
  19.2   40500   0.90   12.60     4781     1787  1.154      2.3MIN      432
  62.0   41500   0.90   12.63     4558     1758  1.212      7.2MIN      259
  15.2   41500   1.60    4.07    12616     5404  1.979*    77.5SEC      394
  15.2   59000   1.60    6.94     5390     3110  1.997*     1.0MIN      263
 234.9   60000   1.60    6.93     3051     2958  1.354     15.4MIN     1051
P(S) AVAIL=    0  P(S) REQ=    0 AT  5.78G, 30000 FT,MACH 1.20(CL=0.51)
   8.0   30000   1.20    7.97    14895    14848  1.932*     0.7MIN      327
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.92G, 30000 FT,MACH 0.90(CL=0.77)
  10.7   30000   0.90    8.52    11848    11827  1.864*     1.2MIN      445
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.50G, 30000 FT,MACH 0.90(CL=0.77)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.56G, 50000 FT,MACH 1.60(CL=0.36)
   0.0   30000   0.90    0.0         0        0  0.0        0.0MIN        0
  10.2   30000   1.60    2.54    19520     8823  2.045*    49.9SEC        0
DROP STORES AT 50000. FEET
 250.0   63000   1.60    6.93     2634     2562  1.358     16.3MIN      973
   0.0       0   0.90    0.0         0        0  0.0        0.0MIN        0
 100.0   51500   0.90   12.43     2330     1403  1.149     11.6MIN      315
  63.9       0   0.29   11.43    16018     1450  1.767     20.0MIN      367
   0.0       0   0.0     0.0         0        0  0.0        0.0MIN      322
COMBAT WEIGHT= 22406.LBS.
RUN ON 11/29/78 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC  (2) CDAFYJ18 ENGINES  FTRLAST PO
LAR
```

1787-158W

TRACTOR ROCKET APPLICATION

TO

MSLPC/FIGHTER CONFIG NO. 007LPC

ESCAPE FACTORS DATA

****RESULTS****

WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W

WING-AREA= 365	AR= 3.00	T/C-ROOT=.045	L.E SWEEP=57.0	TAPER=0.150
V.T.-AREA= 68	AR= 1.03	T/C(AVG)=.036	.25 SWEEP=52.8	TAPER=0.168
H.T.-AREA= 56	AR= 2.68	T/C(AVG)=.036	.25 SWEEP=46.7	TAPER=0.160
BODY-AREA= 810	WD= 5.11	LEN.,FT.= 56	VOL:TOT.= 1154	PRESS= 80
ENG. NACELLES AREA = 0		CAP.AREA= 346	DUCT LEN=17.41	ENGS.= 2
TOTAL WETTED AREA = 1612		CL(MAX.)=1.03	LANDING STALL SPEED,KN= 117	

HORIZONTAL TAIL ARM, FEET= 16.7 DRAG RISE MACH NUMBER = 0.900
OVERALL FINENESS RATIO =10.00 TOTAL THRUST-SLS,MAXIMUM A/B= 23982
TAKEOFF WING LOADING, W/S= 64.8 TAKEOFF THRUST-TO-WEIGHT,T/W= 1.016
TAKEOFF DIST.(GROUND RUN)= 923 LANDING DISTANCE(GROUND RUN)= 1064

WEIGHT BREAKDOWN

WT. EMPTY =	15312	WING =	1799	FUEL SYST.=	887	AIR COND=	432
CREW WT. =	274	V.TAIL=	285	MISC.PROP.=	161	HANDLING=	6
RACKS,PYL=	300	H.TAIL=	303	SURF.CNTLS=	518	FIXED WT=	1891
MISC.U.L.=	290	BODY =	2544	HYDRAULICS=	323	GROWTH =	0
STORE WT.=	1000	GEAR =	813	ELECTRICAL=	567	FLT.DES.=	22319
TOT.FUEL =	6421	E.SECT=	469	AVIONICS =	1736	STR.DEN.=	7.83
TAKEOFF WT.=	23598	ENGINE=	2296	FURN+EQUIP=	273	AIRFRAME=	9037

FUEL BREAKDOWN

DIST.	ALT.	MACH	L/D	T.AVL	DRAG	SFC	TIME	FUEL
0.0	0	0.0	0.0	15567	1090	1.643	15.0MIN	448
0.0	0	0.40	11.60	23065	1988	1.904*	0.0MIN	179
0.0	0	0.40	0.0	0	0	0.0	0.0MIN	0
3.6	0	0.90	4.18	17030	5477	1.309	29.6SEC	168
19.2	40500	0.90	12.59	4762	1781	1.154	2.3MIN	430
62.0	41500	0.90	12.62	4540	1752	1.212	7.2MIN	258
15.2	41500	1.60	4.07	12567	5386	1.979*	77.5SEC	393
15.2	59000	1.60	6.94	5369	3100	1.997*	1.0MIN	262
234.8	60000	1.60	6.93	3039	2948	1.354	15.4MIN	1047
P(S) AVAIL= 0 P(S) REQ= 0 AT 5.78G, 30000 FT,MACH 1.20(CL=0.51)								
8.0	30000	1.20	7.97	14837	14790	1.932*	0.7MIN	326
P(S) AVAIL= 0 P(S) REQ= 0 AT 4.92G, 30000 FT,MACH 0.90(CL=0.77)								
10.7	30000	0.90	8.52	11802	11781	1.864*	1.2MIN	443
P(S) AVAIL= 0 P(S) REQ= 0 AT 4.50G, 30000 FT,MACH 0.90(CL=0.77)								
P(S) AVAIL= 0 P(S) REQ= 0 AT 2.56G, 50000 FT,MACH 1.60(CL=0.36)								
0.0	30000	0.90	0.0	0	0	0.0	0.0MIN	0
10.2	30000	1.60	2.54	19444	8793	2.045*	49.9SEC	0
DROP STORES AT 50000. FEET								
250.0	63000	1.60	6.93	2623	2553	1.358	16.3MIN	970
0.0	0	0.90	0.0	0	0	0.0	0.0MIN	0
100.0	51500	0.90	12.42	2818	1398	1.149	11.6MIN	314
62.6	0	0.28	11.36	15941	1452	1.756	20.0MIN	863
0.0	0	0.0	0.0	0	0	0.0	0.0MIN	321

COMBAT WEIGHT= 22319.LBS.
RUN ON 01/27/79 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC (2) CDAFYJ18 ENGINES FTRLAST PO
LAR

1787-159W

SHIELD/CANOPY APPLICATION

TO

MSLPC/FIGHTER CONFIG. NO. 007 LPC

ESCAPE FACTORS DATA

```
                              ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  365  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=57.0   TAPER=0.150
V.T.-AREA=   68  AR= 1.03  T/C(AVG)=.036  .25 SWEEP=52.8   TAPER=0.168
H.T.-AREA=   56  AR= 2.68  T/C(AVG)=.036  .25 SWEEP=46.7   TAPER=0.160
BODY-AREA=  810  WD= 5.11  LEN.,FT.=  56  VOL:TOT.= 1154   PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 346  DUCT LEN=17.41   ENGS.=    2
TOTAL WETTED AREA  = 1612  CL(MAX.)=1.03  LANDING STALL SPEED,KN= 117
HORIZONTAL TAIL ARM, FEET= 16.7   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   = 9.99   TOTAL THRUST-SLS,MAXIMUM A/B= 23983
TAKEOFF WING LOADING, W/S= 64.8   TAKEOFF THRUST-TO-WEIGHT,T/W= 1.016
TAKEOFF DIST.(GROUND RUN)=  923   LANDING DISTANCE(GROUND RUN)=  1064

                              WEIGHT BREAKDOWN
WT. EMPTY   =   15305  WING   =  1799  FUEL SYST.=  887  AIR COND=   432
  CREW WT. =      282  V.TAIL=    285  MISC.PROP.=  161  HANDLING=     6
  RACKS,PYL=      300  H.TAIL=    303  SURF.CNTLS=  518  FIXED WT=  1891
  MISC.U.L.=      290  BODY   =  2544  HYDRAULICS=  323  GROWTH   =     0
  STORE WT.=     1000  GEAR   =   813  ELECTRICAL=  567  FLT.DES.= 22320
  TOT.FUEL =     6422  E.SECT=    469  AVIONICS  = 1736  STR.DEN.=  7.83
TAKEOFF WT.=    23599  ENGINE=   2296  FURN+EQUIP=  265  AIRFRAME=  9030

                              FUEL BREAKDOWN
 DIST.    ALT.   MACH     L/D     T.AVL     DRAG    SFC       TIME       FUEL
   0.0       0   0.0     0.0     15568     1090   1.643     15.0MIN      448
   0.0       0   0.40   11.60    23066     1988   1.904*     0.0MIN      179
   0.0       0   0.40    0.0         0        0   0.0        0.0MIN        0
   3.6       0   0.90    4.18    17031     5477   1.309     29.6SEC      168
  19.2   40500   0.90   12.59     4762     1781   1.154      2.3MIN      430
  62.0   41500   0.90   12.62     4540     1752   1.212      7.2MIN      258
  15.2   41500   1.60    4.07    12568     5386   1.979*    77.5SEC      393
  15.2   59000   1.60    6.94     5370     3100   1.997*     1.0MIN      262
 234.8   60000   1.60    6.93     3039     2948   1.354     15.4MIN     1047
P(S) AVAIL=    0  P(S) REQ=    0 AT   5.78G, 30000 FT,MACH 1.20(CL=0.51)
   8.0   30000   1.20    7.97    14838    14791   1.932*     0.7MIN      326
P(S) AVAIL=    0  P(S) REQ=    0 AT   4.92G, 30000 FT,MACH 0.90(CL=0.77)
  10.7   30000   0.90    8.52    11802    11781   1.864*     1.2MIN      443
P(S) AVAIL=    0  P(S) REQ=    0 AT   4.50G, 30000 FT,MACH 0.90(CL=0.77)
P(S) AVAIL=    0  P(S) REQ=    0 AT   2.56G, 50000 FT,MACH 1.60(CL=0.36)
   0.0   30000   0.90    0.0         0        0   0.0        0.0MIN        0
  10.2   30000   1.60    2.54    19445     8794   2.045*    49.9SEC        0
DROP STORES AT 50000. FEET
 250.0   63000   1.60    6.93     2624     2553   1.358     16.3MIN      970
   0.0       0   0.90    0.0         0        0   0.0        0.0MIN        0
 100.0   51500   0.90   12.42     2819     1398   1.149     11.6MIN      314
  62.6       0   0.28   11.36    15942     1452   1.756     20.0MIN      863
   0.0       0   0.0     0.0         0        0   0.0        0.0MIN      321
COMBAT WEIGHT= 22320.LBS.
RUN ON 11/29/78 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC  (2) CDAFYJ18 ENGINES  FTRLAST PO
LAR
```

1787-160W

"B" VARIANT APPLICATION

TO

MSLPC/FIGHTER CONFIG. NO. 007 LPC

ESCAPE FACTORS DATA

```
                          ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  365  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=57.0  TAPER=0.150
V.T.-AREA=   68  AR= 1.03  T/C(AVG)=.036  .25 SWEEP=52.8  TAPER=0.168
H.T.-AREA=   56  AR= 2.68  T/C(AVG)=.036  .25 SWEEP=46.7  TAPER=0.160
BODY-AREA=  811  WD= 5.12  LEN.,FT.=  56  VOL:TOT.= 1155  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 347  DUCT LEN=17.41  ENGS.=    2
TOTAL WETTED AREA  = 1614  CL(MAX.)=1.03  LANDING STALL SPEED,KN= 117
HORIZONTAL TAIL ARM, FEET= 16.7   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   = 9.99   TOTAL THRUST-SLS,MAXIMUM A/B= 24021
TAKEOFF WING LOADING, W/S= 64.8   TAKEOFF THRUST-TO-WEIGHT,T/W= 1.016
TAKEOFF DIST.(GROUND RUN)=  923   LANDING DISTANCE(GROUND RUN)=  1064

                         WEIGHT BREAKDOWN
WT. EMPTY  =  15341  WING   =  1803  FUEL SYST.=  888  AIR COND=   432
  CREW WT. =    273  V.TAIL=   286  MISC.PROP.=  161  HANDLING=     6
  RACKS,PYL=    300  H.TAIL=   304  SURF.CNTLS=  519  FIXED WT=  1891
  MISC.U.L.=    290  BODY   =  2546  HYDRAULICS=  324  GROWTH   =     0
  STORE WT.=   1000  GEAR   =   814  ELECTRICAL=  567  FLT.DES.= 22356
  TOT.FUEL =   6432  E.SECT=   470  AVIONICS  = 1736  STR.DEN.=  7.85
TAKEOFF WT.=  23637  ENGINE=  2301  FURN+EQUIP=  286  AIRFRAME=  9062

                         FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D    T.AVL    DRAG    SFC      TIME      FUEL
   0.0       0   0.0    0.0    15593    1092  1.643    15.0MIN      448
   0.0       0   0.40  11.60   23103    1990  1.904*    0.0MIN      179
   0.0       0   0.40   0.0        0       0  0.0       0.0MIN        0
   3.6       0   0.90   4.18   17059    5484  1.309    29.6SEC      168
  19.2   40500   0.90  12.60    4770    1784  1.154     2.3MIN      431
  62.0   41500   0.90  12.63    4547    1755  1.212     7.2MIN      258
  15.2   41500   1.60   4.07   12588    5393  1.979*   77.5SEC      394
  15.2   59000   1.60   6.94    5378    3104  1.997*    1.0MIN      263
 234.8   60000   1.60   6.93    3044    2952  1.354    15.4MIN     1049
P(S) AVAIL=    0  P(S) REQ=    0 AT  5.78G, 30000 FT,MACH 1.20(CL=0.51)
   8.0   30000   1.20   7.97   14862   14815  1.932*    0.7MIN      327
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.92G, 30000 FT,MACH 0.90(CL=0.77)
  10.7   30000   0.90   8.52   11821   11800  1.864*    1.2MIN      444
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.50G, 30000 FT,MACH 0.90(CL=0.77)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.56G, 50000 FT,MACH 1.60(CL=0.36)
   0.0   30000   0.90   0.0        0       0  0.0       0.0MIN        0
  10.2   30000   1.60   2.54   19477    8806  2.045*   49.9SEC        0
DROP STORES AT 50000. FEET
 250.0   63000   1.60   6.93    2628    2557  1.358    16.3MIN      971
   0.0       0   0.90   0.0        0       0  0.0       0.0MIN        0
 100.0   51500   0.90  12.43    2823    1400  1.149    11.6MIN      314
  63.9       0   0.29  11.42   15982    1447  1.767    20.0MIN      865
   0.0       0   0.0    0.0        0       0  0.0       0.0MIN      322
COMBAT WEIGHT= 22356.LBS.
RUN ON 11/29/78 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC  (2) CDAFVJ18 ENGINES  FTRLAST PD
LAR
```

1787-161W

CURVED TRACK APPLICATION

TO

MSLPC/FIGHTER CONFIG. NO. 007 LPC

ESCAPE FACTORS DATA

```
                             ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  364  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=57.0  TAPER=0.150
V.T.-AREA=   68  AR= 1.03  T/C(AVG)=.036  .25 SWEEP=52.8  TAPER=0.168
H.T.-AREA=   56  AR= 2.68  T/C(AVG)=.036  .25 SWEEP=46.7  TAPER=0.160
BODY-AREA=  810  WD= 5.11  LEN.,FT.=  56  VOL:TOT.= 1153  PRESS=    80
ENG. NACELLES AREA =    0  CAP.AREA= 346  DUCT LEN=17.40  ENGS.=     2
TOTAL WETTED AREA  = 1611  CL(MAX.)=1.03  LANDING STALL SPEED,KN= 117
HORIZONTAL TAIL ARM, FEET= 16.7   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   =10.00   TOTAL THRUST-SLS,MAXIMUM A/B= 23962
TAKEOFF WING LOADING, W/S= 64.8   TAKEOFF THRUST-TO-WEIGHT,T/W= 1.016
TAKEOFF DIST.(GROUND RUN)=  923   LANDING DISTANCE(GROUND RUN)=  1064

                             WEIGHT BREAKDOWN
WT. EMPTY   =  15290  WING   =  1797  FUEL SYST.=  887  AIR COND=   432
  CREW WT. =     281  V.TAIL=    285  MISC.PROP.=  161  HANDLING=     6
  RACKS,PYL=     300  H.TAIL=    303  SURF.CNTLS=  518  FIXED WT=  1891
  MISC.U.L.=     290  BODY   =  2543  HYDRAULICS=  323  GROWTH   =    0
  STORE WT.=    1000  GEAR   =   812  ELECTRICAL=  567  FLT.DES.= 22301
  TOT.FUEL =    6416  E.SECT=    469  AVIONICS  = 1736  STR.DEN.=  7.82
TAKEOFF WT.=   23578  ENGINE=   2294  FURN+EQUIP=  259  AIRFRAME=  9019

                             FUEL BREAKDOWN
 DIST.     ALT.   MACH     L/D     T.AVL     DRAG    SFC      TIME       FUEL
   0.0        0   0.0     0.0     15554     1089  1.643    15.0MIN       447
   0.0        0   0.40   11.60    23046     1986  1.904*    0.0MIN       179
   0.0        0   0.40    0.0         0        0  0.0       0.0MIN         0
   3.6        0   0.90    4.18    17016     5473  1.309    29.6SEC       168
  19.2    40500   0.90   12.59     4758     1780  1.154     2.3MIN       430
  62.0    41500   0.90   12.62     4536     1751  1.212     7.2MIN       258
  15.2    41500   1.60    4.07    12557     5382  1.979*   77.5SEC       393
  15.2    59000   1.60    6.94     5365     3097  1.997*    1.0MIN       262
 234.8    60000   1.60    6.93     3037     2946  1.354    15.4MIN      1047
P(S) AVAIL=    0  P(S) REQ=    0 AT  5.78G, 30000 FT,MACH 1.20(CL=0.51)
   8.0    30000   1.20    7.97    14825    14778  1.932*    0.7MIN       326
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.92G, 30000 FT,MACH 0.90(CL=0.77)
  10.7    30000   0.90    8.52    11792    11771  1.864*    1.2MIN       443
P(S) AVAIL=    0  P(S) REQ=    0 AT  4.50G, 30000 FT,MACH 0.90(CL=0.77)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.56G, 50000 FT,MACH 1.60(CL=0.36)
   0.0    30000   0.90    0.0         0        0  0.0       0.0MIN         0
  10.2    30000   1.60    2.54    19428     8787  2.045*   49.9SEC         0
DROP STORES AT 50000. FEET
 250.0    63000   1.60    6.92     2621     2551  1.358    16.3MIN       969
   0.0        0   0.90    0.0         0        0  0.0       0.0MIN         0
 100.0    51500   0.90   12.42     2816     1397  1.149    11.6MIN       314
  62.6        0   0.28   11.36    15928     1451  1.756    20.0MIN       862
   0.0        0   0.0     0.0         0        0  0.0       0.0MIN       321
COMBAT WEIGHT= 22300.LBS.
RUN ON 11/29/78 WITH 1977B VERSION OF CISE
MSLPC MACH 1.6 FIGHTER FWC  (2) CDAFVJ18 ENGINES  FTRLAST PO
LAR
```

1787-162W

```
                COMPUTERIZED INITIAL SIZING ESTIMATE

***LAND-BASED DESIGN***  FIGHTER-ATTACK  F.WING-CANARD  AVIONICS=1425
RETAINED STORE-WT=    0  0.80 DRAG=0.0   .95 DRAG=0.0   1.1 DRAG=0.0
         1.4 DRAG= 0.0   1.80 DRAG=0.0   2.1 DRAG=0.0   2.5 DRAG=0.0
EXTERNAL STORE-WT=    0  0.80 DRAG=0.0   .95 DRAG=0.0   1.1 DRAG=0.0
         1.4 DRAG= 0.0   1.80 DRAG=0.0   2.1 DRAG=0.0   2.5 DRAG=0.0
EXT.TANK-CAPACITY=    0  0.80 DRAG=0.0   .95 DRAG=0.0   1.1 DRAG=0.0
         1.4 DRAG= 0.0   1.80 DRAG=0.0   2.1 DRAG=0.0   2.5 DRAG=0.0
INTERNAL STORE WT= 4000  CREW + PASS= 1  MAX.MACH=2.30  ULT.L.F.= 9.8
NO.OF INTERNAL RACKS= 2  EXT. RACKS = 0  PYLON NO. = 0  FIXED WT=1632
WING MTL. PCT.SAVING=33  V.TAIL PCT.=31  H.TAIL PCT=27  BODY PCT. =29
GEAR MTL. PCT.SAVING=25  A.IND. PCT.=27  GROWTH PCT= 0  SFC FACTOR= 5
SEA-LEVEL MAX.MACH=1.20  ENG. T/W= 0.0   *ENGINE EQUIPPED WITH AN A/B
HOURLY RATES-ENG.= 0.0   MANUFAC.= 0.0   MFG.SUP= 0.0   Q.CNTL.= 0.0
FLIGHT TEST RATE = 0.0   MANGMENT= 0.0   TOOLING= 0.0   $ REF.YR=   0
PRODUCTION QUANT.=    0  IOC YEAR=    0  G.AND A=.0     PROFIT =.0
 THE MISSION PROFILE IS SHOWN BELOW
    WARMUP 15.00 MINUTES AT   7 PCT POWER
    TAKEOFF AND ACCELERATE TO CLIMB SPEED WITH 100 PCT MAX.AB
     DUMMY SEGMENT (    0FT/MACH 0.40)
    MINIMUM FUEL ACCEL =100 PCT POWER  TO     0FT/MACH 0.90 IN ***SEC
    CLIMB TO CRUISE ALTITUDE AT MACH 0.90 AND 100 PCT POWER
     CRUISE  400NM. AT BEST ALTITUDE AND MACH NUMBER
     MINIMUM FUEL ACCEL =100 PCT MAX.AB TO 41100FT/MACH 1.50 IN ***SEC
    MINIMUM FUEL ACCEL =100 PCT MAX.AB TO 40000FT/MACH 2.00 IN ***SEC
    CLIMB TO CRUISE ALTITUDE AT MACH 2.00 AND 100 PCT MAX.AB
     CRUISE  250NM. AT 58200 FT AND MACH 2.00
    COMPUTE MAX.TURN CAPABILITY- 58201FT/MACH 2.00 AND 100 PCT MAX.AB
    COMBAT-1.0 TURNS AT 2.246 ,58201FT/MACH 2.00
     COMPUTE MAX.TURN CAPABILITY- 30000FT/MACH 0.90 AND 100 PCT MAX.AB
    COMPUTE MAX.TURN CAPABILITY- 50000FT/MACH 2.00 AND 100 PCT MAX.AB
    DUMMY SEGMENT (30000FT/MACH 0.90)
    MINIMUM TIME ACCEL =100 PCT MAX.AB TO 30000FT/MACH 1.60 IN ***SEC
    DROP EXPENDABLE STORES
     CRUISE  250NM. AT 62750 FT AND MACH 2.00
    DUMMY SEGMENT (45000FT/MACH 0.90)
     CRUISE  400NM. AT BEST ALTITUDE AND MACH NUMBER
     LOITER   20MIN AT      0FT AND BEST MACH NUMBER
    FUEL ALLOWANCE EQUALS  5.0 PERCENT OF TOTAL FUEL
```

1787-163W

CDAF PROGRAM

M2.0 PENETRATOR CONFIG. -006

BASELINE DATA

```
                                  ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  548  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  111  AR= 1.01  T/C(AVG)=.036  ,25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   84  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1305  WD= 6.25  LEN.,FT.=  77  VOL:TOT.= 2295  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 575  DUCT LEN=18.10  ENGS.=    2
TOTAL WETTED AREA  = 2540  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 23.1   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   =11.77   TOTAL THRUST-SLS,MAXIMUM A/B= 34061
TAKEOFF WING LOADING, W/S= 77.7   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.800
TAKEOFF DIST.(GROUND RUN)= 1490   LANDING DISTANCE(GROUND RUN)=  1144

                                 WEIGHT BREAKDOWN
WT. EMPTY   =  23377  WING   =  3547  FUEL SYST.= 1524  AIR COND=   515
  CREW WT.  =    240  V.TAIL=    516  MISC.PROP.=  192  HANDLING=     8
  RACKS,PYL=     150  H.TAIL=    538  SURF.CNTLS=  759  FIXED WT=  1832
  MISC.U.L.=     406  BODY   =  4550  HYDRAULICS=  472  GROWTH   =    0
  STORE WT.=    4000  GEAR   =  1232  ELECTRICAL=  790  FLT.DES.= 39700
  TOT.FUEL  =  14381  E.SECT=    921  AVIONICS  = 2138  STR.DEN.=  6.59
TAKEOFF WT.=   42555  ENGINE=   3579  FURN+EQUIP=  257  AIRFRAME= 15134

                                 FUEL BREAKDOWN
 DIST.    ALT.   MACH     L/D     T.AVL     DRAG    SFC       TIME        FUEL
   0.0       0   0.0      0.0     21828     1528  1.644     15.0MIN       628
   0.0       0   0.40    12.01    34080     3476  1.907*     0.0MIN       326
   0.0       0   0.40     0.0         0        0  0.0        0.0MIN         0
   4.3       0   0.90     5.20    26197     7969  1.299     36.2SEC       303
  27.2   39100   0.90    12.79     6322     3179  1.123      3.1MIN       772
 346.7   41100   0.90    12.75     5747     2996  1.130     40.3MIN      2344
  15.1   41100   1.50     5.79    17952     6539  1.988*    80.6SEC       572
  11.1   40000   2.00     3.24    27068    11541  2.110*    39.9SEC       507
  12.0   58200   2.00     6.14    11249     5995  2.119*     0.7MIN       382
 238.0   58200   2.00     5.96     5891     5853  1.469     12.4MIN      1837
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.22G, 58201 FT,MACH 2.00(CL=0.31)
  60.9   58201   2.00     6.97    11248    11247  2.119*     3.2MIN      1266
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.93G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90     0.0         0        0  0.0        0.0MIN         0
  11.5   30000   1.60     3.48    29874    11418  2.078*    57.4SEC         0
DROP STORES AT 50000. FEET
 250.0   62750   2.00     5.96     4722     4709  1.473     13.1MIN      1556
   0.0   45000   0.90     0.0         0        0  0.0        0.0MIN         0
 400.0   49300   0.90    12.73     3887     2058  1.141     46.5MIN      1884
  63.6       0   0.29    11.53    22915     2161  1.756     20.0MIN      1284
   0.0       0   0.0      0.0         0        0  0.0        0.0MIN       719
COMBAT WEIGHT= 39697.LBS.
RUN ON 11/15/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAGT POLA
R
```

1787-164W

BASELINE M2.0 PENETRATOR

ASL-495F-006A

BASELINE DATA

```
                        ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  532  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  108  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   82  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1270  WD= 6.16  LEN.,FT.=  76  VOL:TOT.= 2208  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 553  DUCT LEN=17.80  ENGS.=    2
TOTAL WETTED AREA  = 2469  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.72   TOTAL THRUST-SLS,MAXIMUM A/B= 32783
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1143

                        WEIGHT BREAKDOWN
WT. EMPTY   =   22578  WING   =  3408  FUEL SYST.= 1488  AIR COND=   515
  CREW WT. =      279  V.TAIL=    500  MISC.PROP.=  189  HANDLING=     8
  RACKS,PYL=      150  H.TAIL=    517  SURF.CNTLS=  743  FIXED WT=  1632
  MISC.U.L.=      396  BODY   =  4417  HYDRAULICS=  462  GROWTH   =     0
  STORE WT.=     4000  GEAR   =  1197  ELECTRICAL=  781  FLT.DES.= 38472
  TOT.FUEL =    13821  E.SECT=    881  AVIONICS  = 2138  STR.DEN.=  6.67
TAKEOFF WT.=    41225  ENGINE=   3418  FURN+EQUIP=  278  AIRFRAME= 14722

                        FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D    T.AVL    DRAG   SFC      TIME       FUEL
   0.0       0   0.0     0.0    21009    1471  1.644    15.0MIN      604
   0.0       0   0.40   12.00   32801    3370  1.907*    0.0MIN      316
   0.0       0   0.40    0.0        0      .0  0.0       0.0MIN        0
   4.4       0   0.90    5.18   25214    7745  1.299    36.5SEC      294
  27.0   38900   0.90   12.79    6144    3080  1.123     3.1MIN      745
 346.8   41200   0.90   12.74    5505    2906  1.128    40.3MIN     2272
  15.1   41200   1.50    5.96   17195    6161  1.988*   81.0SEC      551
  11.0   40000   2.00    3.33   26052   10880  2.110*   39.7SEC      483
  11.9   58200   2.00    6.28   10827    5681  2.119*    0.6MIN      365
 238.1   58200   2.00    6.10    5670    5546  1.472    12.5MIN     1747
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.22G, 58201 FT,MACH 2.00(CL=0.31)
  60.7   58201   2.00    7.05   10826   10825  2.119*    3.2MIN     1214
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.95G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90    0.0        0       0  0.0       0.0MIN        0
  11.5   30000   1.60    3.57   28753   10780  2.078*   57.3SEC        0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.10    4544    4457  1.476    13.1MIN     1478
   0.0   45000   0.90    0.0        0       0  0.0       0.0MIN        0
 400.0   49300   0.90   12.72    3742    1992  1.140    46.5MIN     1823
  63.6       0   0.29   11.52   22053    2092  1.751    20.0MIN     1240
   0.0       0   0.0     0.0        0       0  0.0       0.0MIN      691
COMBAT WEIGHT= 38471.LBS.
RUN ON 01/30/79 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFVJ16 ENGINES PENLAST POLA
R
```

1787-165W

MSLPC APPLICATION

WITH RADAR

PENETRATOR CONFIG NO. 006LPC-1

AERO FACTORS DATA

```
                          ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  526  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  102  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   81  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1259  WD= 6.12  LEN.,FT.=  76  VOL:TOT.= 2182  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 547  DUCT LEN=17.74  ENGS.=    2
TOTAL WETTED AREA  = 2435  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.75   TOTAL THRUST-SLS,MAXIMUM A/B= 32414
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                        WEIGHT BREAKDOWN
WT. EMPTY  =  22356  WING   =  3357  FUEL SYST.= 1474  AIR COND=   515
  CREW WT. =    279  V.TAIL=    474  MISC.PROP.=  188  HANDLING=     8
  RACKS,PYL=    150  H.TAIL=    509  SURF.CNTLS=  736  FIXED WT=  1632
  MISC.U.L.=    393  BODY   =  4375  HYDRAULICS=  459  GROWTH   =     0
  STORE WT.=   4000  GEAR   =  1185  ELECTRICAL=  778  FLT.DES.= 38057
  TOT.FUEL =  13576  E.SECT=    870  AVIONICS  = 2138  STR.DEN.=  6.67
TAKEOFF WT.=  40755  ENGINE=   3372  FURN+EQUIP=  278  AIRFRAME= 14557

                        FUEL BREAKDOWN
  DIST.    ALT.  MACH    L/D   T.AVL    DRAG   SFC      TIME      FUEL
   0.0        0  0.0     0.0   20773    1454  1.644    15.0MIN     598
   0.0        0  0.40  12.02   32432    3328  1.907*    0.0MIN     312
   0.0        0  0.40    0.0       0       0  0.0       0.0MIN       0
   4.4        0  0.90   5.20   24931    7640  1.299    36.4SEC     291
  27.2    39000  0.90  12.80    6046    3042  1.123     3.1MIN     739
 346.8    41100  0.90  12.76    5469    2868  1.129    40.3MIN    2243
  15.0    41100  1.50   5.98   17084    6067  1.988*   80.3SEC     542
  10.9    40000  2.00   3.35   25759   10670  2.110*   39.5SEC     477
  11.8    58200  2.00   6.32   10705    5580  2.119*    0.6MIN     358
 238.2    58200  2.00   6.15    5607    5451  1.473    12.5MIN    1684
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.6    58201  2.00   7.07   10704   10703  2.119*    3.2MIN    1198
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.95G, 50000 FT,MACH 2.00(CL=0.31)
   0.0    30000  0.90    0.0       0       0  0.0       0.0MIN       0
  11.5    30000  1.60   3.60   28429   10573  2.078*   57.1SEC       0
DROP STORES AT 50000. FEET
 250.0    62750  2.00   6.14    4493    4380  1.477    13.1MIN    1426
   0.0    45000  0.90    0.0       0       0  0.0       0.0MIN       0
 400.0    49300  0.90  12.73    3699    1971  1.140    46.5MIN    1803
  63.6        0  0.29  11.53   21806    2070  1.750    20.0MIN    1226
   0.0        0  0.0     0.0       0       0  0.0       0.0MIN     679
COMBAT WEIGHT= 38055.LBS.
RUN ON 01/24/79 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
```

1787-166W

DEFLECTION WEDGE APPLICATION

TO

MSLPC (RADAR) PENETRATOR CONFIG. NO. 006 LPC-1

ESCAPE FACTORS DATA

```
                              ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  527  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  102  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   81  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1260  WD= 6.12  LEN.,FT.=  76  VOL:TOT.= 2184  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 548  DUCT LEN=17.75  ENGS.=    2
TOTAL WETTED AREA  = 2438  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   =11.74   TOTAL THRUST-SLS,MAXIMUM A/B= 32471
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1146

                              WEIGHT BREAKDOWN
WT. EMPTY  =  22409  WING  =  3365  FUEL SYST.= 1475  AIR COND=   515
  CREW WT. =    274  V.TAIL=   475  MISC.PROP.=  188  HANDLING=     8
  RACKS,PYL=    150  H.TAIL=   511  SURF.CNTLS=  737  FIXED WT=  1632
  MISC.U.L.=    393  BODY  =  4380  HYDRAULICS=  460  GROWTH  =     0
  STORE WT.=   4000  GEAR  =  1187  ELECTRICAL=  778  FLT.DES.= 38123
  TOT.FUEL =  13599  E.SECT=   872  AVIONICS  = 2138  STR.DEN.=  6.68
TAKEOFF WT.=  40826  ENGINE=  3379  FURN+EQUIP=  302  AIRFRAME= 14602

                              FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D     T.AVL     DRAG   SFC       TIME      FUEL
   0.0       0   0.0     0.0     20809     1457  1.644    15.0MIN      599
   0.0       0   0.40   12.02    32489     3333  1.907*    0.0MIN      313
   0.0       0   0.40    0.0         0        0  0.0       0.0MIN        0
   4.4       0   0.90    5.20    24974     7650  1.299    36.4SEC      291
  27.2   39000   0.90   12.80     6056     3047  1.123     3.1MIN      740
 346.8   41100   0.90   12.76     5478     2873  1.129    40.3MIN     2247
  15.0   41100   1.50    5.38    17114     6076  1.988*   80.3SEC      543
  10.9   40000   2.00    3.35    25804    10686  2.110*   39.5SEC      478
  11.8   58200   2.00    6.32    10724     5539  2.119*    0.6MIN      359
 238.2   58200   2.00    6.15     5616     5459  1.473    12.5MIN     1687
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.6   58201   2.00    7.07    10723    10722  2.119*    3.2MIN     1200
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.95G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90    0.0         0        0  0.0       0.0MIN        0
  11.5   30000   1.60    3.60    28479    10589  2.078*   57.1SEC        0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.14     4501     4387  1.477    13.1MIN     1428
   0.0   45000   0.90    0.0         0        0  0.0       0.0MIN        0
 400.0   49300   0.90   12.74     3706     1975  1.140    46.5MIN     1807
  63.6       0   0.29   11.53    21844     2074  1.750    20.0MIN     1228
   0.0       0   0.0     0.0         0        0  0.0       0.0MIN      680
COMBAT WEIGHT= 38122.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
```

1787-167W

TRACTOR ROCKET APPLICATION

TO

MSLPC/PENETRATOR CONFIG NO. 006LPC-1

ESCAPE FACTORS DATA

****RESULTS****

WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA= 526 AR= 3.00 T/C-ROOT=.045 L.E SWEEP=59.0 TAPER=0.200
V.T.-AREA= 102 AR= 1.01 T/C(AVG)=.036 .25 SWEEP=54.1 TAPER=0.153
H.T.-AREA= 81 AR= 2.59 T/C(AVG)=.036 .25 SWEEP=47.9 TAPER=0.152
BODY-AREA= 1259 WD= 6.12 LEN.,FT.= 76 VOL:TOT.= 2181 PRESS= 80
ENG. NACELLES AREA = 0 CAP.AREA= 546 DUCT LEN=17.73 ENGS.= 2
TOTAL WETTED AREA = 2434 CL(MAX.)=0.97 LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7 DRAG RISE MACH NUMBER = 0.900
OVERALL FINENESS RATIO =11.75 TOTAL THRUST-SLS,MAXIMUM A/B= 32385
TAKEOFF WING LOADING, W/S= 77.5 TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498 LANDING DISTANCE(GROUND RUN)= 1145

WEIGHT BREAKDOWN

WT. EMPTY =	22336	WING =	3354	FUEL SYST.=	1473	AIR COND=	515
CREW WT. =	274	V.TAIL=	473	MISC.PROP.=	188	HANDLING=	8
RACKS,PYL=	150	H.TAIL=	509	SURF.CNTLS=	735	FIXED WT=	1632
MISC.U.L.=	392	BODY =	4373	HYDRAULICS=	459	GROWTH =	0
STORE WT.=	4000	GEAR =	1184	ELECTRICAL=	778	FLT.DES.=	38022
TOT.FUEL =	13564	E.SECT=	870	AVIONICS =	2138	STR.DEN.=	6.67
TAKEOFF WT.=	40718	ENGINE=	3369	FURN+EQUIP=	273	AIRFRAME=	14542

FUEL BREAKDOWN

DIST.	ALT.	MACH	L/D	T.AVL	DRAG	SFC	TIME	FUEL
0.0	0	0.0	0.0	20754	1453	1.644	15.0MIN	597
0.0	0	0.40	12.02	32403	3325	1.907*	0.0MIN	312
0.0	0	0.40	0.0	0	0	0.0	0.0MIN	0
4.4	0	0.90	5.19	24908	7635	1.299	36.4SEC	290
27.2	39000	0.90	12.79	6040	3040	1.123	3.1MIN	738
346.8	41100	0.90	12.75	5464	2866	1.129	40.3MIN	2242
15.0	41100	1.50	5.98	17068	6062	1.988*	80.3SEC	542
10.9	40000	2.00	3.35	25736	10662	2.110*	39.5SEC	477
11.8	58200	2.00	6.32	10695	5576	2.119*	0.6MIN	358
238.2	58200	2.00	6.15	5602	5446	1.473	12.5MIN	1683

P(S) AVAIL= 0 P(S) REQ= 0 AT 2.23G, 58201 FT,MACH 2.00(CL=0.31)

60.6	58201	2.00	7.07	10695	10693	2.119*	3.2MIN	1197

P(S) AVAIL= 0 P(S) REQ= 0 AT 3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL= 0 P(S) REQ= 0 AT 2.95G, 50000 FT,MACH 2.00(CL=0.31)

0.0	30000	0.90	0.0	0	0	0.0	0.0MIN	0
11.5	30000	1.60	3.60	28404	10565	2.078*	57.1SEC	0

DROP STORES AT 50000. FEET

250.0	62750	2.00	6.14	4489	4376	1.477	13.1MIN	1424
0.0	45000	0.90	0.0	0	0	0.0	0.0MIN	0
400.0	49300	0.90	12.73	3696	1969	1.140	46.5MIN	1801
63.6	0	0.29	11.53	21786	2068	1.750	20.0MIN	1225
0.0	0	0.0	0.0	0	0	0.0	0.0MIN	678

COMBAT WEIGHT= 38020.LBS.
RUN ON 01/27/79 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R

1787-168W

SHIELD/CANOPY APPLICATION

TO

MSLPC (RADAR) PENETRATOR CONFIG. NO. 006 LPC-1

ESCAPE FACTORS DATA

```
                          ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  526  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  102  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   81  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1259  WD= 6.12  LEN.,FT.=  76  VOL:TOT.= 2181  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 546  DUCT LEN=17.74  ENGS.=    2
TOTAL WETTED AREA  = 2434  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7   DRAG RISE MACH NUMBER      = 0.900
OVERALL FINENESS RATIO   =11.75   TOTAL THRUST-SLS,MAXIMUM A/B= 32386
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                         WEIGHT BREAKDOWN
WT. EMPTY   =  22329  WING   =  3354  FUEL SYST.= 1473  AIR COND=   515
  CREW WT. =     282  V.TAIL=    473  MISC.PROP.=  188  HANDLING=     8
  RACKS,PYL=     150  H.TAIL=    509  SURF.CNTLS=  735  FIXED WT=  1632
  MISC.U.L.=     392  BODY   =  4373  HYDRAULICS=  459  GROWTH   =     0
  STORE WT.=    4000  GEAR   =  1185  ELECTRICAL=  778  FLT.DES.= 38024
  TOT.FUEL =   13565  E.SECT=    870  AVIONICS   = 2138  STR.DEN.=  6.67
TAKEOFF WT.=   40720  ENGINE=   3369  FURN+EQUIP=  265  AIRFRAME= 14534

                         FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D     T.AVL     DRAG    SFC      TIME       FUEL
   0.0       0   0.0     0.0     20755     1453  1.644     15.0MIN      597
   0.0       0   0.40   12.02    32404     3325  1.907*     0.0MIN      312
   0.0       0   0.40    0.0         0        0  0.0        0.0MIN        0
   4.4       0   0.90    5.19    24909     7635  1.299     36.4SEC      291
  27.2   39000   0.90   12.79     6040     3040  1.123      3.1MIN      738
 346.8   41100   0.90   12.75     5464     2866  1.129     40.3MIN     2242
  15.0   41100   1.50    5.98    17069     6062  1.988*    80.3SEC      542
  10.9   40000   2.00    3.35    25737    10662  2.110*    39.5SEC      477
  11.8   58200   2.00    6.32    10696     5576  2.119*     0.6MIN      358
 238.2   58200   2.00    6.15     5602     5446  1.473     12.5MIN     1683
P(S) AVAIL=   0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.6   58201   2.00    7.07    10695    10694  2.119*     3.2MIN     1197
P(S) AVAIL=   0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=   0  P(S) REQ=    0 AT  2.95G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90    0.0         0        0  0.0        0.0MIN        0
  11.5   30000   1.60    3.60    28405    10565  2.078*    57.1SEC        0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.14     4489     4377  1.477     13.1MIN     1424
   0.0   45000   0.90    0.0         0        0  0.0        0.0MIN        0
 400.0   49300   0.90   12.73     3696     1969  1.140     46.5MIN     1801
  63.6       0   0.29   11.53    21787     2068  1.750     20.0MIN     1225
   0.0       0   0.0     0.0         0        0  0.0        0.0MIN      678
COMBAT WEIGHT= 38022.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFVJ16 ENGINES PENLAST POLA
R
```

1787-169W

"B" VARIANT APPLICATION

TO

MSLPC (RADAR) PENETRATOR CONFIG. NO. 006 LPC-1

ESCAPE FACTORS DATA

```
                         ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  526  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  102  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   81  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1259  WD= 6.12  LEN.,FT.=  76  VOL:TOT.= 2182  PRESS=    30
ENG. NACELLES AREA =    0  CAP.AREA= 547  DUCT LEN=17.74  ENGS.=     2
TOTAL WETTED AREA  = 2436  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.75   TOTAL THRUST-SLS,MAXIMUM A/B= 32420
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                         WEIGHT BREAKDOWN
WT. EMPTY   =  22368  WING   =  3358  FUEL SYST.= 1474  AIR COND=   515
  CREW WT. =     273  V.TAIL=    474  MISC.PROP.=  188  HANDLING=     8
  RACKS,PYL=     150  H.TAIL=    510  SURF.CNTLS=  736  FIXED WT=  1632
  MISC.U.L.=     393  BODY  =   4376  HYDRAULICS=  459  GROWTH   =    0
  STORE WT.=    4000  GEAR  =   1186  ELECTRICAL=  778  FLT.DES.= 38064
  TOT.FUEL =   13579  E.SECT=    870  AVIONICS  = 2138  STR.DEN.=  6.68
TAKEOFF WT.=   40763  ENGINE=   3373  FURN+EQUIP=  286  AIRFRAME= 14568

                         FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D     T.AVL     DRAG    SFC       TIME       FUEL
   0.0       0   0.0     6.0     20777     1454  1.644     15.0MIN       598
   0.0       0   0.40   12.02    32438     3329  1.907*     0.0MIN       313
   0.0       0   0.40    0.0         0        0  0.0        0.0MIN         0
   4.4       0   0.90    5.20    24936     7641  1.299     36.4SEC       291
  27.2   39000   0.90   12.80     6047     3043  1.123      3.1MIN       739
 346.8   41100   0.90   12.76     5470     2869  1.129     40.3MIN      2244
  15.0   41100   1.50    5.98    17087     6068  1.988*    80.3SEC       542
  10.9   40000   2.00    3.35    25764    10672  2.110*    39.5SEC       477
  11.8   58200   2.00    6.32    10707     5581  2.119*     0.6MIN       358
 238.2   58200   2.00    6.15     5608     5451  1.473     12.5MIN      1685
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.6   58201   2.00    7.07    10707    10705  2.119*     3.2MIN      1198
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.95G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90    0.0         0        0  0.0        0.0MIN         0
  11.5   30000   1.60    3.60    28435    10575  2.078*    57.1SEC         0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.14     4494     4381  1.477     13.1MIN      1426
   0.0   45000   0.90    0.0         0        0  0.0        0.0MIN         0
 400.0   49300   0.90   12.73     3700     1971  1.140     46.5MIN      1804
  63.6       0   0.29   11.53    21810     2071  1.750     20.0MIN      1226
   0.0       0   0.0     0.0         0        0  0.0        0.0MIN       679
COMBAT WEIGHT= 38062.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFVJ16 ENGINES PENLAST POLA
R
```

178 '-170W

CURVED TRACK APPLICATION

TO

MSLPC (RADAR) PENETRATOR CONFIG. NO. 006 LPC-1

ESCAPE FACTORS DATA

```
                          ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  525  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=  102  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   81  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1258  WD= 6.11  LEN.,FT.=  76  VOL:TOT.= 2180  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 546  DUCT LEN=17.73  ENGS.=    2
TOTAL WETTED AREA  = 2432  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.7   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.75   TOTAL THRUST-SLS,MAXIMUM A/B= 32366
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                          WEIGHT BREAKDOWN
WT. EMPTY  =  22314  WING  =  3351  FUEL SYST.= 1472  AIR COND=   515
  CREW WT. =    281  V.TAIL=   473  MISC.PROP.=  188  HANDLING=     8
  RACKS,PYL=    150  H.TAIL=   508  SURF.CNTLS=  735  FIXED WT=  1632
  MISC.U.L.=    392  BODY  =  4371  HYDRAULICS=  459  GROWTH  =     0
  STORE WT.=   4000  GEAR  =  1184  ELECTRICAL=  777  FLT.DES.= 38001
  TOT.FUEL =  13557  E.SECT=   869  AVIONICS  = 2138  STR.DEN.=  6.66
TAKEOFF WT.=  40695  ENGINE=  3366  FURN+EQUIP=  259  AIRFRAME= 14522

                          FUEL BREAKDOWN
 DIST.    ALT.   MACH    L/D    T.AVL     DRAG    SFC      TIME      FUEL
   0.0       0   0.0     0.0    20742     1452  1.644    15.0MIN      597
   0.0       0   0.40   12.02   32384     3324  1.907*    0.0MIN      312
   0.0       0   0.40    0.0        0        0  0.0       0.0MIN        0
   4.4       0   0.90    5.19   24894     7631  1.299    36.5SEC      290
  27.2   39000   0.90   12.79    6037     3038  1.123     3.1MIN      738
 346.8   41100   0.90   12.75    5461     2865  1.129    40.3MIN     2240
  15.0   41100   1.50    5.98   17059     6059  1.988*   80.3SEC      541
  11.0   40000   2.00    3.35   25721    10656  2.110*   39.5SEC      476
  11.8   58200   2.00    6.32   10689     5573  2.119*    0.6MIN      358
 238.2   58200   2.00    6.15    5598     5443  1.473    12.5MIN     1682
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.6   58201   2.00    7.07   10689    10687  2.119*    3.2MIN     1196
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.95G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90    0.0        0        0  0.0       0.0MIN        0
  11.5   30000   1.60    3.60   28388    10560  2.078*   57.1SEC        0
DROP STORES AT 50000   FEET
 250.0   62750   2.00    6.14    4487     4374  1.477    13.1MIN     1423
   0.0   45000   0.90    0.0        0        0  0.0       0.0MIN        0
 400.0   49300   0.90   12.73    3694     1968  1.140    46.5MIN     1800
  63.6       0   0.29   11.53   21774     2067  1.750    20.0MIN     1224
   0.0       0   0.0     0.0        0        0  0.0       0.0MIN      678
COMBAT WEIGHT= 37999.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
```

1787-171W

MSLPC APPLICATION

WITHOUT RADAR

PENETRATOR CONFIG NO. 006LPC-2

AERO FACTORS DATA

```
                                ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  521   AR= 3.00   T/C-ROOT=.045   L.E SWEEP=59.0   TAPER=0.200
V.T.-AREA=   93   AR= 1.01   T/C(AVG)=.036   .25 SWEEP=54.1   TAPER=0.153
H.T.-AREA=   80   AR= 2.59   T/C(AVG)=.036   .25 SWEEP=47.9   TAPER=0.152
BODY-AREA= 1248   WD= 6.08   LEN.,FT.=  75   VOL:TOT.= 2156   PRESS=    80
ENG. NACELLES AREA =     0   CAP.AREA= 542   DUCT LEN=17.67   ENGS.=     2
TOTAL WETTED AREA  = 2396   CL(MAX.)=0.97   LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.6   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   =11.79   TOTAL THRUST-SLS,MAXIMUM A/B= 32107
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                                WEIGHT BREAKDOWN
WT. EMPTY   =  22146   WING   =  3316   FUEL SYST.= 1463   AIR CUND=    515
  CREW WT.  =    279   V.TAIL=    431   MISC.PROP.=  187   HANDLING=      8
  RACKS,PYL=     150   H.TAIL=    503   SURF.CNTLS=  728   FIXED WT=   1632
  MISC.U.L.=     390   BODY   =  4338   HYDRAULICS=  457   GROWTH   =      0
  STORE WT.=    4000   GEAR   =  1176   ELECTRICAL=  775   FLT.DES.= 37705
  TOT.FUEL =   13403   E.SEC.=    861   AVIONICS  = 2138   STR.DEN.=   6.68
TAKEOFF WT.=   40369   ENGINE=   3334   FURN+EQUIP=  278   AIRFRAME= 14393

                                FUEL BREAKDOWN
  DIST.     ALT.   MACH     L/D     T.AVL     DRAG    SFC       TIME       FUEL
   0.0         0   0.0      0.0     20576     1440  1.644     15.0MIN      592
   0.0         0   0.40    12.06    32125     3286  1.907*     0.0MIN      309
   0.0         0   0.40     0.0         0        0  0.0        0.0MIN        0
   4.4         0   0.90     5.23    24694     7519  1.299     36.4SEC      288
  27.2     39000   0.90    12.84     5988     3004  1.123      3.1MIN      730
 347.0     41100   0.90    12.79     5417     2833  1.129     40.3MIN     2218
  14.9     41100   1.50     6.03    16922     5959  1.988*    80.0SEC      535
  10.9     40000   2.00     3.38    25515    10475  2.110*    39.3SEC      470
  11.7     58200   2.00     6.36    10604     5489  2.119*     0.6MIN      353
 238.3     58200   2.00     6.20     5553     5361  1.474     12.5MIN     1659
P(S) AVAIL=   0   P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.4   58201    2.00     7.09    10603    10602  2.119*      3.2MIN     1184
P(S) AVAIL=   0   P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=   0   P(S) REQ=    0 AT  2.96G, 50000 FT,MACH 2.00(CL=0.31)
   0.0     30000   0.90     0.0         0        0  0.0        0.0MIN        0
  11.4     30000   1.60     3.63    28160    10379  2.078*    56.9SEC        0
DROP STORES AT 50000. FEET
 250.0     62750   2.00     6.19     4451     4307  1.478     13.1MIN     1403
   0.0     45000   0.90     0.0         0        0  0.0        0.0MIN        0
 400.0     49200   0.90    12.78     3682     1946  1.141     46.5MIN     1781
  63.6         0   0.29    11.57    21599     2045  1.753     20.0MIN     1213
   0.0         0   0.0      0.0         0        0  0.0        0.0MIN      670
COMBAT WEIGHT= 37703.LBS.
RUN ON 01/24/79 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
1787.172W
```

DEFLECTION WEDGE APPLICATION

TO

MSLPC/PENETRATOR CONFIG NO. 006LPC-2

ESCAPE FACTORS DATA

```
                           ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  522  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=   93  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   80  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1249  WD= 6.08  LEN.,FT.=  75  VOL:TOT.= 2158  PPESS=   80
ENG. NACELLES APEA =    0  CAP.AREA= 543  DUCT LEN=17.67  ENGS.=    2
TOTAL WETTED AREA  = 2399  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.6   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.79   TOTAL THRUST-SLS,MAXIMUM A/B= 32163
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1146

                           WEIGHT BREAKDOWN
WT. EMPTY   =  22198  WING   =  3324  FUEL SYST.= 1465  AIR COND=   515
  CREW WT. =     274  V.TAIL=    432  MISC.PROP.=  187  HANDLING=     8
  RACKS,PYL=     150  H.TAIL=    504  SURF.CNTLS=  729  FIXED WT=  1632
  MISC.U.L.=     390  BODY   =  4342  HYDRAULICS=  457  GROWTH  =     0
  STORE WT.=    4000  GEAR   =  1177  ELECTRICAL=  775  FLT.DES.= 37771
  TOT.FUEL =   13426  E.SECT=    862  AVIONICS  = 2138  STR.DEN.=  6.69
TAKEOFF WT.=   40440  ENGINE=   3341  FURN+EQUIP=  302  AIRFRAME= 14437

                           FUEL BREAKDOWN
 DIST.    ALT.   MACH     L/D    T.AVL     DRAG    SFC       TIME       FUEL
   0.0       0   0.0      0.0    20612     1443  1.644     15.0MIN       593
   0.0       0   0.40   12.06    32181     3291  1.907*     0.0MIN       310
   0.0       0   0.40     0.0        0        0  0.0        0.0MIN         0
   4.4       0   0.90    5.23    24738     7529  1.299     36.4SEC       288
  27.2   39000   0.90   12.84     5999     3009  1.123      3.1MIN       731
 347.0   41100   0.90   12.80     5427     2833  1.129     40.3MIN      2221
  14.9   41100   1.50    6.03    16952     5968  1.988*    80.0SEC       536
  10.9   40000   2.00    3.33    25560    10491  2.110*    39.3SEC       471
  11.7   58200   2.00    6.37    10622     5498  2.119*     0.6MIN       353
 233.3   58200   2.00    6.20     5563     5370  1.474     12.5MIN      1662
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.4   58201   2.00    7.09    10622    10620  2.119*     3.2MIN      1186
P(S) AVAIL=    0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=    0 AT  2.96G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90     0.0        0        0  0.0        0.0MIN         0
  11.4   30000   1.60    3.63    28209    10395  2.078*    56.9SEC         0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.19     4459     4314  1.478     13.1MIN      1405
   0.0   45000   0.90     0.0        0        0  0.0        0.0MIN         0
 400.0   49200   0.90   12.78     3688     1949  1.141     46.5MIN      1785
  63.6       0   0.29   11.57    21637     2049  1.753     20.0MIN      1215
   0.0       0   0.0      0.0        0        0  0.0        0.0MIN       671
COMBAT WEIGHT= 37769.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
```

1782-173W

TRACTOR ROCKET APPLICATION

TO

MSLPC/PENETRATOR CONFIG NO. 006LPC-2

ESCAPE FACTORS DATA

```
                          ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  521  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=   92  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   80  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1247  WD= 6.08  LEN.,FT.=  75  VOL:TOT.= 2154  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 541  DUCT LEN=17.66  ENGS.=    2
TOTAL WETTED AREA  = 2394  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.6   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.80   TOTAL THRUST-SLS,MAXIMUM A/B= 32078
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                         WEIGHT BREAKDOWN
WT. EMPTY  =  22127  WING   =  3312  FUEL SYST.= 1462  AIR COND=   515
  CREW WT. =    274  V.TAIL=    430  MISC.PROP.=  187  HANDLING=     8
  RACKS,PYL=    150  H.TAIL=    502  SURF.CNTLS=  728  FIXED WT=  1632
  MISC.U.L.=    390  BODY  =   4335  HYDRAULICS=  456  GROWTH  =     0
  STORE WT.=   4000  GEAR  =   1175  ELECTRICAL=  775  FLT.DES.= 37671
  TOT.FUEL =  13392  E.SECT=    860  AVIONICS  = 2138  STR.DEN.=  6.67
TAKEOFF WT.=  40333  ENGINE=   3330  FURN+EQUIP=  273  AIRFRAME= 14378

                          FUEL BREAKDOWN
 DIST.    ALT.   MACH     L/D    T.AVL     DRAG    SFC      TIME       FUEL
   0.0       0   0.0      0.0    20558     1439  1.644    15.0MIN       591
   0.0       0   0.40   12.06    32096     3283  1.907*    0.0MIN       309
   0.0       0   0.40     0.0        0        0  0.0       0.0MIN         0
   4.4       0   0.90    5.23    24672     7514  1.299    36.4SEC       287
  27.2   39000   0.90   12.84     5983     3002  1.123     3.1MIN       729
 347.0   41100   0.90   12.79     5412     2831  1.129    40.3MIN      2216
  14.9   41100   1.50    6.03    16907     5954  1.988*   80.0SEC       535
  10.9   40000   2.00    3.38    25492    10467  2.110*   39.3SEC       470
  11.7   58200   2.00    6.36    10594     5485  2.119*    0.6MIN       352
 238.3   58200   2.00    6.20     5549     5357  1.474    12.5MIN      1658
P(S) AVAIL=   0  P(S) REQ=   0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.4   58201   2.00    7.08    10594    10592  2.119*    3.2MIN      1183
P(S) AVAIL=   0  P(S) REQ=   0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=   0  P(S) REQ=   0 AT  2.96G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90     0.0        0        0  0.0       0.0MIN         0
  11.4   30000   1.60    3.63    28135    10371  2.078*   56.9SEC         0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.19     4447     4303  1.478    13.1MIN      1402
   0.0   45000   0.90     0.0        0        0  0.0       0.0MIN         0
 400.0   49200   0.90   12.78     3679     1944  1.141    46.5MIN      1780
  63.6       0   0.29   11.57    21580     2043  1.753    20.0MIN      1212
   0.0       0   0.0      0.0        0        0  0.0       0.0MIN       670
COMBAT WEIGHT= 37669.LBS.
RUN ON 01/24/79 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
1787-174W
```

SHIELD/CANOPY APPLICATION

TO

MSLPC/PENETRATOR CONFIG NO. 006LPC-2

ESCAPE FACTORS DATA

```
                                ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  521  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=   92  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   80  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1247  WD= 6.08  LEN.,FT.=  75  VOL:TOT.= 2154  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 541  DUCT LEN=17.66  ENGS.=    2
TOTAL WETTED AREA  = 2394  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.6   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO   =11.30   TOTAL THRUST-SLS,MAXIMUM A/B= 32079
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                                WEIGHT BREAKDOWN
WT. EMPTY   =  22119  WING   =  3312  FUEL SYST.= 1462  AIR COND=    515
  CREW WT. =     232  V.TAIL=    430  MISC.PROP.=  187  HANDLING=      8
  RACKS.PYL=     150  H.TAIL=    502  SURF.CNTLS=  728  FIXED WT=   1632
  MISC.U.L.=     390  BODY   =  4335  HYDRAULICS=  456  GROWTH   =     0
  STORE WT.=    4000  GEAR   =  1175  ELECTRICAL=  775  FLT.DES.= 37671
  TOT.FUEL =   13392  E.SECT=    860  AVIONICS  = 2133  STR.DEN.=   6.67
TAKEOFF WT.=   40333  ENGINE=   3330  FURN+EQUIP=  265  AIRFRAME= 14370

                                FUEL BREAKDOWN
 DIST.    ALT.   MACH     L/D     T.AVL     DRAG    SFC      TIME       FUEL
   0.0       0   0.0      0.0     20558     1439  1.644     15.0MIN      591
   0.0       0   0.40   12.06     32096     3283  1.907*     0.0MIN      309
   0.0       0   0.40    0.0          0        0  0.0        0.0MIN        0
   4.4       0   0.90    5.23     24673     7514  1.299     36.4SEC      287
  27.2   39000   0.90   12.84      5983     3002  1.123      3.1MIN      729
 347.0   41100   0.90   12.79      5412     2831  1.129     40.3MIN     2216
  14.9   41100   1.50    6.03     16907     5954  1.988*    80.0SEC      535
  10.9   40000   2.00    3.38     25492    10467  2.110*    39.3SEC      470
  11.7   58200   2.00    6.36     10594     5485  2.119*     0.6MIN      352
 233.3   58200   2.00    6.20      5549     5357  1.474     12.5MIN     1658
P(S) AVAIL=    0  P(S) REQ=     0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.4   58201   2.00    7.08     10594    10592  2.119*     3.2MIN     1183
P(S) AVAIL=    0  P(S) REQ=     0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=    0  P(S) REQ=     0 AT  2.96G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90    0.0          0        0  0.0        0.0MIN        0
  11.4   30000   1.60    3.63     28135    10371  2.078*    56.9SEC        0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.19      4447     4303  1.478     13.1MIN     1402
   0.0   45000   0.90    0.0          0        0  0.0        0.0MIN        0
 400.0   49200   0.90   12.78      3679     1944  1.141     46.5MIN     1730
  63.6       0   0.29   11.57     21580     2043  1.753     20.0MIN     1212
   0.0       0   0.0     0.0          0        0  0.0        0.0MIN      670
COMBAT WEIGHT= 37670.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFYJ16 ENGINES PENLAST POLA
R
```

1787-175W

"B" SEAT VARIANT APPLICATION

TO

MSLPC/PENETRATOR CONFIG NO. 006LPC-2

ESCAPE FACTORS DATA

```
                             ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  521  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0  TAPER=0.200
V.T.-AREA=   93  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1  TAPER=0.153
H.T.-AREA=   80  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9  TAPER=0.152
BODY-AREA= 1248  WD= 6.08  LEN.,FT.=  75  VOL:TOT.= 2156  PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 542  DUCT LEN=17.67  ENGS.=    2
TOTAL WETTED AREA  = 2396  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.6   DRAG RISE MACH NUMBER        = 0.900
OVERALL FINENESS RATIO    =11.79  TOTAL THRUST-SLS,MAXIMUM A/B= 32113
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                            WEIGHT BREAKDOWN
WT. EMPTY   =  22157  WING   =  3317  FUEL SYST.= 1463  AIR COND=   515
  CREW WT.  =    273  V.TAIL=    431  MISC.PROP.=  187  HANDLING=     3
  RACKS,PYL=     150  H.TAIL=    503  SURF.CNTLS=  728  FIXED WT=  1632
  MISC.U.L.=     390  BODY   =  4338  HYDRAULICS=  457  GROWTH   =    0
  STORE WT.=    4000  GEAR   =  1176  ELECTRICAL=  775  FLT.DES.= 37712
  TOT.FUEL =   13406  E.SECT=    861  AVIONICS  = 2138  STR.DEN.=  6.68
TAKEOFF WT.=   40376  ENGINE=   3335  FURN+EQUIP=  286  AIRFRAME= 14403

                            FUEL BREAKDOWN
 DIST.    ALT.   MACH     L/D    T.AVL     DRAG   SFC      TIME         FUEL
   0.0       0   0.0      0.0    20580     1441  1.644    15.0MIN        592
   0.0       0   0.40   12.06    32130     3286  1.907*    0.0MIN        309
   0.0       0   0.40     0.0        0        0  0.0       0.0MIN          0
   4.4       0   0.90    5.23    24699     7520  1.299    36.4SEC        288
  27.2   33000   0.90   12.34     5989     3005  1.123     3.1MIN        730
 347.0   41100   0.90   12.79     5418     2834  1.129    40.3MIN       2218
  14.9   41100   1.50    6.03    16925     5960  1.988*   80.0SEC        535
  10.9   40000   2.00    3.38    25520    10477  2.110*   39.3SEC        470
  11.7   58200   2.00    6.36    10605     5490  2.119*    0.6MIN        353
 238.3   58200   2.00    6.20     5554     5362  1.474    12.5MIN       1659
P(S) AVAIL=   0  P(S) REQ=    0 AT  2.23G, 58201 FT,MACH 2.00(CL=0.31)
  60.4   58201   2.00    7.09    10605    10604  2.119*    3.2MIN       1184
P(S) AVAIL=   0  P(S) REQ=    0 AT  3.50G, 30000 FT,MACH 0.90(CL=0.71)
P(S) AVAIL=   0  P(S) REQ=    0 AT  2.96G, 50000 FT,MACH 2.00(CL=0.31)
   0.0   30000   0.90     0.0        0        0  0.0       0.0MIN          0
  11.4   30000   1.60    3.63    28165    10381  2.078*   56.9SEC          0
DROP STORES AT 50000. FEET
 250.0   62750   2.00    6.19     4452     4308  1.478    13.1MIN       1403
   0.0   45000   0.90     0.0        0        0  0.0       0.0MIN          0
 400.0   49200   0.90   12.78     3683     1946  1.141    46.5MIN       1782
  63.6       0   0.29   11.57    21603     2045  1.753    20.0MIN       1213
   0.0       0   0.0      0.0        0        0  0.0       0.0MIN        670
COMBAT WEIGHT= 37710.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) COAFYJ16 ENGINES PENLAST POLA
R
```

1787-176W

CURVED TRACK APPLICATION

TO

MSLPC/PENETRATOR CONFIG NO. 006LPC-2

ESCAPE FACTORS DATA

```
                              ****RESULTS****
WING SIZING CRITERION: INPUTTED W/S
THRUST SIZING CRITERION: INPUTTED T/W
WING-AREA=  520  AR= 3.00  T/C-ROOT=.045  L.E SWEEP=59.0   TAPER=0.200
V.T.-AREA=   92  AR= 1.01  T/C(AVG)=.036  .25 SWEEP=54.1   TAPER=0.153
H.T.-AREA=   80  AR= 2.59  T/C(AVG)=.036  .25 SWEEP=47.9   TAPER=0.152
BODY-AREA= 1247  WD= 6.08  LEN.,FT.=  75  VOL:TOT.= 2153   PRESS=   80
ENG. NACELLES AREA =    0  CAP.AREA= 541  DUCT LEN=17.66   ENGS.=    2
TOTAL WETTED AREA  = 2393  CL(MAX.)=0.97  LANDING STALL SPEED,KN= 120
HORIZONTAL TAIL ARM, FEET= 22.6   DRAG RISE MACH NUMBER       = 0.900
OVERALL FINENESS RATIO   =11.80   TOTAL THRUST-SLS,MAXIMUM A/B= 32059
TAKEOFF WING LOADING, W/S= 77.5   TAKEOFF THRUST-TO-WEIGHT,T/W= 0.795
TAKEOFF DIST.(GROUND RUN)= 1498   LANDING DISTANCE(GROUND RUN)=  1145

                              WEIGHT BREAKDOWN
WT. EMPTY   =   22103  WING   =  3309  FUEL SYST.= 1462  AIR COND=   515
  CREW WT.  =     281  V.TAIL=    430  MISC.PROP.=  187  HANDLING=     8
  RACKS,PYL=      150  H.TAIL=    502  SURF.CNTLS=  727  FIXED WT=  1632
  MISC.U.L.=      390  BODY   =  4334  HYDRAULICS=  456  GROWTH   =    0
  STORE WT.=     4000  GEAR   =  1174  ELECTRICAL=  775  FLT.DES.= 37648
  TOT.FUEL =    13384  E.SECT=   7860  AVIONICS  = 2138  STR.DEN.=  6.67
TAKEOFF WT.=    40309  ENGINE=   3328  FURN+EQUIP=  259  AIRFRAME= 14357
```

FUEL BREAKDOWN

DIST.	ALT.	MACH	L/D	T.AVL	DRAG	SFC	TIME	FUEL
0.0	0	0.0	0.0	20545	1438	1.644	15.0MIN	591
0.0	0	0.40	12.06	32077	3281	1.907*	6.0MIN	309
0.0	0	0.40	0.0	0	0	0.0	0.0MIN	0
4.4	0	0.90	5.23	24658	7510	1.299	36.4SEC	287
27.2	39000	0.90	12.83	5979	3000	1.123	3.1MIN	729
347.0	41100	0.90	12.79	5409	2829	1.129	40.3MIN	2215
14.9	41100	1.50	6.03	16897	5951	1.988*	80.0SEC	534
10.9	40000	2.00	3.38	25477	10462	2.110*	39.3SEC	469
11.7	58200	2.00	6.36	10588	5482	2.119*	0.6MIN	352
233.3	58200	2.00	6.20	5545	5354	1.474	12.5MIN	1657
P(S) AVAIL= 0 P(S) REQ= 0 AT 2.23G, 58201 FT,MACH 2.00(CL=0.31)								
60.4	58201	2.00	7.08	10587	10586	2.119*	3.2MIN	1182
P(S) AVAIL= 0 P(S) REQ= 0 AT 3.50G, 30000 FT,MACH 0.90(CL=0.71)								
P(S) AVAIL= 0 P(S) REQ= 0 AT 2.96G, 50000 FT,MACH 2.00(CL=0.31)								
0.0	30000	0.90	0.0	0	0	0.0	0.0MIN	0
11.4	30000	1.60	3.63	28118	10366	2.078*	56.9SEC	0
DROP STORES AT 50000. FEET								
250.0	62750	2.00	6.18	4444	4301	1.478	13.1MIN	1401
0.0	45000	0.90	0.0	0	0	0.0	0.0MIN	0
400.0	49200	0.90	12.78	3676	1942	1.141	46.5MIN	1779
63.6	0	0.29	11.57	21567	2041	1.753	20.0MIN	1211
0.0	0	0.0	0.0	0	0	0.0	0.0MIN	669

```
COMBAT WEIGHT= 37647.LBS.
RUN ON 12/19/78 WITH 1977B VERSION OF CISE
MSLPC MACH 2 PENTRATOR FWC (2) CDAFVJ16 ENGINES PENLAST POLA
R
```

1787-177W

APPENDIX F

REFERENCES

1. "High Acceleration Cockpit Applications Study," AFFDL-TR-75-139 Air Force Flight Dynamics Lab., WPAFB, Ohio, November 1975.

2. "High Acceleration Cockpits for Advanced Fighter Aircraft", AFFDL-TR-74-48, Air Force Flight Dynamics Lab., WPAFB, Ohio, May 1974.

3. Beale, R.B., "Fluidic Thrust Vector Control for the Stabilization of Man Ejection Seat Systems," AFFDL-TR-75-105, Air Force Flight Dynamics Lab., WPAFB, Ohio, July 1975.

4. Burns, J.W., "Re-evaluation of a Tilt-Back Seat as a Means of Increasing Acceleration Tolerance," Biodynamics Branch, USAF School of Aerospace Medicine, Brooks AFB, Texas, January 1975.

5. "Modular Lift Cycle Cost Model (MLCCM), for Advanced Aircraft System, Phase II," AFFDL-TR-78-40, Volume 1, April 1978.

6. Hinz, W.W. & Miller, E.H., "Propulsion Integration of a Supersonic Cruise Strike-Fighter," AIAA Paper No. 79-0100, January 1979.

7. "Partial Crew System Tests - EA-6B Yankee Escape System," Report No. 1812-1 thru 12, Stanley Aviation Corp., Denver, Colorado, September 1972.

8. Stone, W.J., "Performance and Design of a Vertical Seeking Seat Steering System," 14th Annual SAFE Conference and Trade Exhibit.

9. "Supersonic Upward Ejection Escape System," Report No. ZP-28-004, Convair Division of General Dynamics, San Diego, California.

10. White, B.J., "Aeromechanical Properties of Ejection Seat Escape Systems," AFFDL-TR-74-57.

☆U.S.Government Printing Office: 1980 — 657-084/439